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TOXIC EMISSIONS FROM AIRCRAFT ENGINES:

A SEARCH OF AVAILABLE LITERATURE

Air RISC

AIR RISK INFORMATION SUPPORT CENTER

Toxic Emissions From Aircraft Engines

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1.0 INTRODUCTION AND PURPOSE

Aviation fuels are used for piston and turbine engines. Gasoline is used for piston engines, while a kerosine-like "jet fuel" is used for turbine engines. Aviation gasoline is composed primarily of straight-chain petroleum compounds, but has a lower vapor pressure than automotive gasoline. Many piston aircraft have a supplemental type certificate that allows them to use automotive gasoline. Turbine (jet) engine jet fuel is made in several grades for military and civil use. Differences among the grades are mostly related to volatility, moisture, and freezing point.

The aircraft fleet in the United States is about 198,000 aircraft. While most of the aircraft are general aviation single- and twin-engine piston models, most of the fuel consumption is by jet transports and the military. The typical single-engine, general aviation aircraft flies about 1 hour per week and burns about 30 to 80 pounds of fuel per hour. A civil transport flies about 8 hours per day and burns a thousand pounds or more of fuel per hour for each of 2, 3, or 4 engines.

A large amount of research has been performed to characterize the emission of criteria pollutants from automotive engines, and a much smaller body of similar work has been done on jet engines. Comparatively little work has been done to identify the emission of toxic or hazardous air pollutants for either source. Complete characterization of the toxics is difficult because of the many compounds produced during combustion and the difficulties of sampling a hot gas stream issuing freely from an aircraft engine. Speciated emission data from volatile organic compound (VOC) measurements are also scarce. However, the military has performed studies of their engines that provide emission information on total VOCs or on individual organic compounds. The utility of this information for estimating emissions from civil aircraft should be addressed.

One area of concern is risk associated with emissions from helicopters that use landing pads within a city. Of special interest are populations that may be at high risk, such as hospital patients exposed to helicopter engine emissions.

The purpose of this work is to perform a small, preliminary task to find what recent data are available to characterize air toxics from aircraft engines as to specific compounds and their health effects. Specific items of interest are emissions from helicopter, civil, and military engines differentiated by mode of operation such as takeoffs, landings, taxiing, and idle.

2.0 BACKGROUND

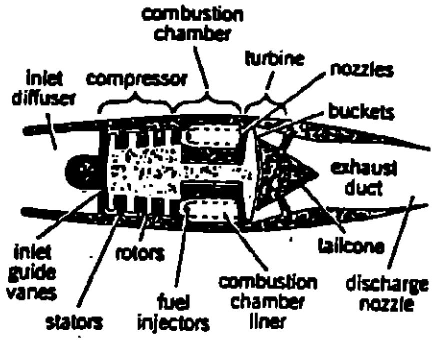
2.1 Aircraft Engines

Aircraft engines can be divided into two broad types: turbojet and piston (hot-air balloons, which use propane burners, are not considered here). Jet engines burn distillate fuels in the kerosene range, and piston engines burn gasoline. Jet engines are used primarily for larger or more expensive aircraft; piston engines are generally used for smaller, private aircraft. Aircraft now in use may have from one to eight engines. Most small, private aircraft have a single piston engine, while most air transport category aircraft have two, three, or four jet engines. Military aircraft range from single or dual engine jet fighters to multi-engine transports (either turbojet or turboprop), to helicopters with (mostly) jet engines or piston engines.

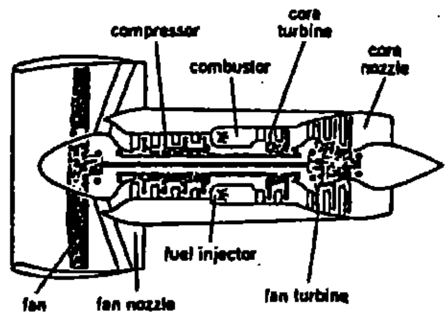
Jet engines operated on aircraft in the United States are manufactured in the U.S. and abroad. U.S. Manufactures include Allied-Signal Garret Engine Div.; CFE Co.; Light Helicopter Turbine Engine Co.; General Electric Co., GE Aircraft Engines; General Motors Allison Gas Turbine Div.; Teledyne CAE, Teledyne Continental; Textron Lycoming Stratford Div.; United Technologies Pratt & Whitney (Government Engine & Space Propulsion and Commercial Engine Business); and Williams International Corp. Foreign manufacturers include Rolls-Royce Canada; Rolls-Royce, Plc.(England); and SNECMA (France). Engines are made in a relatively small number of basic designs, but may have a variety of "dash" numbers to signify specific variants for particular applications. Figure 1 is a schematic illustration of three typical jet engine types. These variants include helicopter models in which the engine may, for example, be mounted vertically instead of horizontally. Emissions from these engines should be similar to emissions from the same model variant mounted in a fixed-wing aircraft. Emissions from foreign-made engines are not expected to differ greatly from those of similar U.S.-made engines because of standards set by the International Civil Aviation Organization (ICAO).

2.2 Differences Between Military and Civil Aircraft Engines

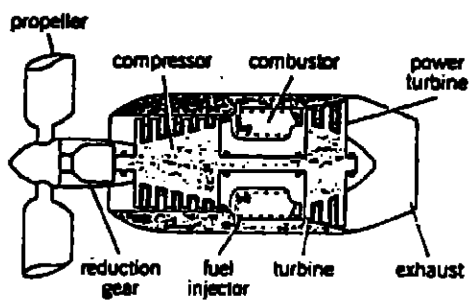
Military aircraft are designed for optimum speed and maneuverability (fighters) or load-carrying, range, and short-field capability (transports). These applications often demand maximum power applied to relatively small airframes. In afterburner mode (not used in civil aircraft), fuel consumption rises dramatically, and does so in an airport setting where emissions of toxic species may be most prevalent. Afterburner is used for take-off and occasionally in flight for bursts of speed in training or combat situations. Civil transports are optimized



(a)



(b)



(c)

Figure 1. Schematic illustrations of typical jet engine types. (a) Turbojet. (b) Turbofan. (c) Turboprop. (Source: McGraw-Hill Encyclopedia of Science and Technology, 7th Ed. McGraw-Hill, Inc., 1992.)

to gain maximum range and payload at minimum cost, including minimum fuel consumption.

Although all emissions testing discussed here has been performed by the military, the same basic engines, with different dash numbers, are used in civil aircraft. Similarly, many engines used in civil aircraft have variants that are used in military aircraft. Without detailed examination of the dash number specifications, it is difficult to assign emission quantities to engine variants other than those tested by the military.

2.3 Fuel Combustion

Fuel combustion in jet engines is a continuous process that supplies heated, expanded gases that are forced through a turbine to drive an associated propeller (turboprop) or are expelled through the aft end of the engine to provide direct thrust (pure-jet). The toxic emissions from jet engines depend on specific engine and fuel type, power setting, and concomitant fuel flow rate. Pollutant formation in a turbine engine emanates from the primary and a secondary combustion zone. In the primary zone, incompletely combusted fuel droplets of about 50 to 200 μm lead to the formation of particulate matter, which is primarily carbon particles. The time for this formation is about 4 ms. Oxidation in the secondary zone leads to particles of about 0.01 to 0.1 μm.[1] During their 6-ms time in the secondary zone, the particles formed earlier are oxidized to varying degrees depending on radial position within the combustion chamber. At the exit of the chamber, agglomerated particles about 0.6 to 0.8 μm remain in the turbine exhaust. Toxic species may be adsorbed or condensed on these particles. Engine power settings and emissions are typically categorized into three major phases of aircraft flight: landings (low power settings), takeoffs and climbs (high power settings), and cruise (optimized power settings). Emission factors for aircraft are often combined over landing and takeoff cycles (LTOs), which are close to the ground. Additionally, cruise emissions may become important because of concerns about dispersion and reaction at high altitudes (due to stratospheric ozone depletion).

Condensed organic species and solid carbon particles form the emissions from aircraft engines. Fuel types affect the quantities and types of emissions formed. For example, JP-5 is a less volatile fuel than JP-4, and may have different emission-forming characteristics. Health risk from the emissions depends on the organic species formed, the quantities and dispersion of pollutants generated, and the availability of receptors.

Methods to reduce emissions, are summarized by Naugle and Fox (1981).[1] They include fuel sectoring for better fuel atomization and higher flame temperature by restricting fuel distribution only to a portion of the combustion chamber. Other methods include enrichment of the primary zone to promote higher flame temperature, delay of dilution air to promote CO consumption, and provision for air blasts to break up fuel droplets.

Changes in fuel composition may also alter emission characteristics. Testing performed by the U.S. Air Force was done with JP-4, but civil aircraft use Jet-A, which is a less volatile fuel and tends to produce less smoke (D. Bahr, General Electric Company, personal communication, August 1992). It is not certain if the smoke reduction also suggests reduction in toxics not adsorbed or condensed on the smoke particles.

3.0 LITERATURE SEARCH

3.1 Sources Searched

A literature search was completed through the Environmental Protection Agency's Online Library System (EPA/OLS), as well as the area university libraries. A further search was conducted through the Research Triangle Institute's Technical Information Center (RTI/TIC) of the Integrated Risk Information System (IRIS). This system is an online database created by the EPA and mounted on the National Library of Medicine's (NLM) TOXNET system. Additional literature searches were completed on the following databases:

- National Technical Information Service (NTIS)
- Defense Technical Information Service (DTIC)
- U.S. Department of Health and Human Services (NIOSHTIC)
- Registry for Toxic Exposure to Chemical Substances (RTECS)
- MEDLINE
- U.S. Department of Medicine (HSDB)
- Health and Safety Ex. (HSELINE)
- Engineering Information, Inc. (EI ENERGY AND ENVIRONMENT)
- TOXLINE
- U.S. Department of Transportation (CHRIS)

These sources were searched for two topical subject areas: Speciated hydrocarbon emissions and toxics from jet turbine engine exhaust, and the health effects thereof. Appendix A includes copies of citations printed from the computer searches.

Finally, in this effort, as in previous studies on the same subject, RTI has maintained frequent professional contact with the military services. The services seem to be the most aggressive agencies in investigating some of the environmental problems addressed by this task. The findings of these literature searches, and a search of RTI's extensive library resources on the subject of aircraft engine emissions is presented in the following sections.

3.2 Origins

With the inception of the Environmental Protection Agency (EPA), and it's predecessor the National Air Pollution Control Agency (NAPCA), there has been concern for the adverse health effects of toxic compounds in the atmosphere. Primarily, because of concern for the task of constructing an emissions inventory of aircraft engine test cell facilities, the U.S. Air Force began, during the 1970's, to develop a database of all known engine emissions data. The purpose of this database was to facilitate the reporting of smoke plume opacity and gaseous emission levels in the form of an engine emissions catalogue for environmental planners. Since then there has been a joint U.S. Air Force/U.S. Navy program to review all data currently available on military gas turbine engines, to assess the validity of these data for current engine models, to identify deficiencies in the data, and to amend the database to keep it current with the military aircraft engine fleet inventory. The primary organization performing these studies for the U.S. Air Force is the Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida. Their counterpart in the U.S. Navy is the Aircraft Environmental Support Office, Naval Aviation Depot, North Island, San Diego, California.

As our knowledge of atmospheric processes and the health effects of adverse toxic chemical compounds has expanded, so has this joint military program expanded to address concerns for speciated hydrocarbon compounds. The following sections present our findings of the current state of knowledge for hydrocarbon emissions from aircraft turbine engine emissions.

3.3 Speciated Hydrocarbon Measurements

Kuhlman and Chuang (1989)[2] have presented a chemical analysis of particulate and vapor portions of the exhaust from the F101 and F110 engines operated at idle, 30 percent, 63 percent, and 100 percent power settings using JP-4 fuel. Particulate-bound organics may be a small fraction of the total organic composition of a turbine engine exhaust (about 5 percent). However, these particulate-bound chemicals and aerosol components of the exhaust, which contain trace elements of heavy metals, may be a significant health consideration because their small size allows inhalation. This study focused primarily on concentration measurements of targeted polycyclic aromatic hydrocarbons (PAH) and nitro-PAH for F101 and F110 engines. The targeted compounds were selected on the basis of their mutagenicity and/or carcinogenic potential, the identification of compounds from related studies, and on the availability of analytical standards.

Gas chromatograph/mass spectrometer (GC/MS) analyses of speciated PAH concentrations, at ng/m^3 levels, in the vapor-phase and in the form of particulate matter for the various power settings are presented.

Spicer, et al (1990)[3] performed a study to determine the gas and particle composition of exhaust from the F101 and F110 turbine engines using JP-4 fuel. Nominal power settings for the F101 engine were idle, 44 percent, 75 percent, intermediate (108 percent at high mach), and Stage 1 augmentation. The F110 tests were completed at idle, 30 percent, 63 percent, intermediate (105 percent at high mach), and Stage 1 augmentation power settings.

Samples of the JP-4 fuel were collected and analyzed for each test run by vaporizing a 1-μL sample of the fuel into helium in a heated cylinder and analyzing a 1-cc sample of the cylinder contents using capillary column gas chromatography. The major organic species identified from these tests were presented as weight percent of the JP-4 fuel.

Gaseous emission concentrations measured from the exhaust for total hydrocarbons as a function of the number of carbon atoms in the compound (ppmC) and NO_x, NO, CO, and CO_2 (ppm) are reported. Gaseous organic species measured during the tests are presented as hydrocarbons, oxygenated species, and compound classes in parts per million carbon (ppmC) for each of the power settings.

Polycyclic Aromatic Hydrocarbon (PAH) emissions collected on XAD-2 resin and analyzed by GC/MS are presented for each engine test in concentrations of μg/m^3. Concentrations of extractable organic matter (mg/m^3) are also reported for each engine test.

Additionally, particulate emissions are reported as particulate mass concentration (mg/m^3) by gravimetric analysis, particle concentration and size distribution, and in terms of smoke number values.

Observational discussions include a comparison of total organics by speciation method versus continuous flame-ionization detection (FID), individual organic species, distribution of emissions by compound class and by carbon number, emission factors, relative emissions of toxic chemicals (benzene, aldehydes, polynuclear aromatic hydrocarbons (PAH), carbon monoxide, nitrogen dioxide), and particle size distributions.

Spicer, et al (1987)[4] also performed gas and particle composition test on the TF41-A2, TF30-P103, and TF30-P109 turbine engines. These tests used JP-4 fuel with the engines operating at power settings of idle, 30 percent, 75 percent, 100 percent, and afterburner (Zone 1) power.

Fuel samples were analyzed for each test by vaporizing 2 µL of fuel into helium in a heated cylinder and analyzing duplicate 1-cc samples of the cylinder contents by capillary column gas chromatography. Results were reported as the weight percent composition of the major organic species identified.

Concentrations of gaseous emissions were reported for total hydrocarbons as carbon (ppmC) and CO, CO_2, NO, and NO_x (ppm). Gaseous organic species were reported as hydrocarbons, oxygenated species, and as distributions of compound classes in concentrations of parts per million carbon (ppmC). Polycyclic aromatic hydrocarbons collected as XAD-2 resin samples were also reported in units of $\mu g/m^3$.

Several methods, including determination of smoke number, gravimetric determination of mass loading, and size distribution measurements by two different techniques were employed to characterize particulate emissions. These findings were reported also.

Discussions include a comparison of total organics by speciation method versus continuous flame-ionization detection (FID), individual hydrocarbon species quantified in the emissions, distribution of emissions by compound class and by carbon number, emission factors, relative emissions of toxic chemicals (benzene, aldehydes, polynuclear aromatic hydrocarbons (PAH), carbon monoxide, nitrogen dioxide), and particle size distributions.

Spicer, et al (1984)[5] reported on a multi-task project, the objectives of which were: (1) to identify and quantify the organic compounds present in gaseous emissions from jet engines and (2) to study the photochemical reactivity of those compounds. The objectives were accomplished through a five-task approach. Tasks 1 and 2 involved development and validation of sampling and analysis methods (see Berry, et al; Ref. 5). Tasks 3-5, the subject of this report, involved: (1) detailed exhaust organic composition studies of two full-scale turbine engines using three grades of military jet fuel, (2) investigation of the photochemical reactivity of the exhausts, and (3) analysis and interpretation of the results.

These organic composition and photochemical reactivity studies were completed on the exhausts of a TF-39 engine (representing a first-generation high-thrust, high-bypass-ratio design) and a CFM-56 engine (representing a recent technology, fuel efficient, advanced emission abatement design). The fuels employed during the full scale engine tests included JP-4, JP-5, and a shale-derived fuel meeting JP-8 specifications. The tests were conducted with both engines using all three fuels at idle, and at 30 percent power and maximum continuous power using JP-5 fuel.

The results of this study are presented in terms of organic compound distribution, carbon balance, relative emission of toxic compounds, comparability of full scale engine and combustor rig exhaust measurements, relative photochemical reactivity of the exhaust products between engines and fuels, comparability of measured and composition-predicted reactivity, and relative contribution of turbine engine exhaust to photochemical air pollution.

Major organic species, including aldehydes and polycyclic aromatic hydrocarbons ("PNA"), measured in the exhaust of each engine operating with each jet fuel are presented for each test. As an example, species found for JP-5 exhaust at idle for the TF-39 engine are shown in Table 1.

Based on the studies reported by Berry, et al (Ref. 6) and Holdren, et al (Ref. 5), the report by AESO (Ref. 11, discussed in Section 3.4) concludes that engine design does not appear to influence the contribution of each toxic constituent to the total organic concentration. However, a comparison of the data reported for the combustion of various fuels (JP-4, JP-5, and JP-8) suggests that fuel composition is the major determinant of exhaust constituents. Since the two engines (TF39 and CFM56) demonstrated comparable exhaust compositions, an average contribution may be representative of the exhaust from comparable gas turbine engines. The report presents the percent contribution, for selected toxic constituents, to the total organic concentration in the exhausts of the TF39 and CFM56 engines during idle operation using JP-5 aviation fuel. These data are presented in Table 2.

Additionally, the percent composition of the major organic species measured in each jet fuel are presented together with standard fuel analysis and GC/FID chromatograms.

Discussions include a comparison of total organics by speciation method versus continuous FID, individual hydrocarbon species quantified in the emissions, distribution of emissions by compound class and by carbon number, ratio of selected aromatic and aliphatic compound pairs, a comparison of the TF-39 Combustor Rig and Full-Scale engine tests, carbonyl compounds measurement methods performance, a comparison of jet turbine engine emission rates to other mobile sources (e.g., for benzene, PAHs, and carbonyl emissions), and the photochemistry experiments.

The study by Berry, et al (1983)[6] had two specific objectives. Task 1 was to develop and validate the sampling and

TABLE 1. MAJOR ORGANIC SPECIES IN EXHAUST OF TF-39 JET ENGINE OPERATING AT IDLE WITH JP-5 FUEL

Constituent	X[1]	Constituent	X
Methane	9.42	Ethane	2.04
Ethylene	62.28	Propane	0.89
Acetylene	16.85	Propene	21.33
1-Butene	7.53	1,3-Butadiene	8.28
c-2-Butene	2.07	1-Pentene	2.95
n-Pentane	0.79	C_5-ene	1.81
2-Methyl-2-Butene	0.85	C_5-ene (sic)	1.92
2-Methylpentane	1.02	1-Hexane	3.15
Benzene	7.45	1-Heptene	1.97
n-Heptane	0.29	Toluene	2.71
Hexanal	0.55	1-Octene	1.29
n-Octane	0.34	Ethylbenzene	10.93
m-p-Xylene	1.48	Styrene	1.38
O-Xylene	0.82	1-Nonene	1.18
n-Nonane	0.52	$C_6H_{18}O_3Si_3$	nd
$C_8H_{24}O_4Si_4$	nd	Phenol	0.64
1-Decene	0.64	n-Decane	1.58
C_4-Benzene	0.76	n-Undecane	2.45
C_3-Cyclohexane	0.86	C_5-Benzene	0.80
Naphthlene	1.99	n-Dodecane	2.84
C_{13}-branched alkane	0.89	C_{14}-branched alkane	0.92
n-Tridecane	2.81	2-Methyl Naphthalene	0.86
1-Methyl Naphthalene	0.88	C_{15}-branched alkane	0.49
n-Tetradecane	1.70	C_{16}-branched alkane	0.56
n-Pentadecane	0.92	n-Hexadecane	0.27
C_{16}-branched alkane (sic)	0.07	n-Heptadecane	0.07
Formaldehyde	14.60	Acetaldehyde	7.50
Acrolein	6.17	Propanal	2.43
Acetone	0.78	Butanal/Crotonaldehyde	3.17
Benzaldehyde	1.87		

[1]X = Average concentration of replicates in ppmC.

TABLE 2. SELECTED POLYCYCLIC AROMATIC HYDROCARBON COMPOUNDS IN GAS TURBINE ENGINE EXHAUST OPERATING AT IDLE WITH JP-5 FUEL AND PERCENT CONTRIBUTION TO THE TOTAL ORGANIC CONCENTRATION

Polycyclic aromatic compound	TF39 Engine		CFM56 Engine		Average (%)
	(ppbC)	(%)	(ppbC)	(%)	
Anthracene	2	<0.001	1	<0.001	<0.001
Benz[a]anthracene	<1	<0.001	<1	<0.001	<0.001
Benzo[a]pyrene	<1	<0.001	<1	<0.001	<0.001
Benzo[e]pyrene	<1	<0.001	<1	<0.001	<0.001
Coronene	<1	<0.001	<1	<0.001	<0.001
Chrysene	<1	<0.001	<1	<0.001	<0.001
Dimethylnaphthalene (isomers)	291	0.08	277	0.14	0.11
Fluoranthene	2	<0.001	2	0.001	<0.001
1-methylnaphthalene	781	0.23	659	0.33	0.28
2-methylnaphthalene	833	0.24	573	0.28	0.26
Naphthalene	1522	0.44	1085	0.54	0.49
Perylene	<1	<0.001	<1	<0.001	<0.001
Phenanthrene	14	0.004	9	0.004	0.004
Pyrene	2	<0.001	3	0.001	<0.001
Total PAH					1.1
Total organic (ppmC)	346		201		

analysis methods for selected organic compounds representative of gas turbine engine emissions. Task 2 was to perform testing on a laboratory combustor rig assembly in which the sampling and analysis methods developed in Task 1 could be evaluated for the determination of the wide range of compounds likely to be emitted from jet engines.

The laboratory combustor rig assembly was constructed and operated with JP-5 jet fuel to simulate an idle power setting of a TF-39 turbine engine.

A discussion of the results presents a distribution of organic components in the combustor rig exhaust, including a summary of organic species measured by various sampling and analysis methods, the total organic species contribution by carbon number, major identified compounds by class, GC/MS identification of exhaust and fuel components, selected aromatic/aliphatic hydrocarbon ratios for exhaust and JP-5 fuel, and carbon balance.

These studies by the U.S. Air Force are the most comprehensive ever performed to quantify and qualify the speciated hydrocarbon compounds in the exhaust of gas turbine engines. A listing of the engines and their usage in military and civil airframes is given in Table 3.

3.4 Species Estimates From Total Hydrocarbons

The U.S. Navy's Aircraft Environmental Support Office has been compiling gaseous emissions data from aircraft engines since 1972, primarily to meet emissions inventory needs for those engines likely to be tested in their engine test cell facilities. Recently, the Navy published a revised version of their Aircraft Engine Emissions Catalog in the form of a handbook (AESO, 1987[7]). The handbook was intended to list only a single representative engine for each type/numeral/model indicator, unless changed emission characteristics, caused by the modification of the engine design, would justify multiple listings. Concurrent to the compilation of the engine emissions data for the handbook, SAE (formerly the Society of Automotive Engineers, Inc.), through its E-31 Committee on Aircraft Exhaust Emission Measurement, published Aerospace Information Report: AIR 1533, which outlined a procedure for the calculation of basic emission parameters for aircraft turbine engines (1982)[8]. This handbook, Gaseous Emissions from Aircraft Engines, brings together the standardized emission calculations recommended by SAE and the selection of measured emissions data of the Aircraft Environmental Support Office. The handbook provides a thorough background discussion of the emission index and methods of calculation, the Aerospace Information Report: AIR 1533, measurements needed to determine

TABLE 3. SPECIATED HYDROCARBON DATA FOR FIXED-WING AIRCRAFT

Engine[a]	Manufacturer	Application[b]		Ref.
		Military	Civilian	
F101	General Electric			c, d
F101-GE-102		B-1B		
F110	General Electric			c, d
F110-GE-100		F-15, F-16		
F110-GE-129		F-16C/D		
F110-GE-400		F-14A, F-14D		
TF41-A2	GM/Allison			e
TF41-A-1B		A-7D		
TF41-A-400, A-2B		A-7E, A-7H		
TF30-P103	UT/Pratt & Whitney			e
TF30-P-3/P-103		F-111A,C,E,K		
TF30-P-7/P-107		FB-111A A/B		
TF30-P-100/P-111		F-111F A/B		
TF30-P109	UT/Pratt & Whitney			e
TF30-P-109		EF-111A		
TF30-P-408		A-7B,C, TA-7C		

[a]Bold face engine model numbers are those for which speciated hydrocarbons were reported by the cited reference.

[b]Applications were taken from the most recent publication of Aviation Week & Space Technology, Specifications, McGraw-Hill Publications, New York, NY, March 1992.

[c]Kuhlman, M.R. and J.C. Chuang, Characterization of Chemicals on Engine Exhaust Particles: F101 AND F110 Engines, ESL-TR-89-20, Tyndall Air Force Base, Florida, August 1989.

[d]Spicer, C.W., M.W. Holdren, D.L. Smith, S.E. Miller, R.N. Smith, D.P. Hughes, Aircraft Emissions Characterization: F101 and F110 Engines, ESL-TR-89-13, Tyndall Air Force Base, Florida, March 1990.

[e]Spicer, C.W., M.W. Holdren, S.E. Miller, D.L. Smith, R.N. Smith, M.R. Kuhlman, and D.P. Hughes, Aircraft Emissions Characterization: TF41-A2, TF30-P103, and TF30-P109 Engines, ESL-TR-87-27, Tyndall Air Force Base, Florida, December 1987.

TABLE 3. SPECIATED HYDROCARBON DATA FOR FIXED-WING AIRCRAFT (cont)

Engine[a]	Manufacturer	Application[b]		Ref.
		Military	Civilian	
TF39	General Electric			f,g,h
TF39-GE-1C		C-5A, C-5B		
CFM-56	GE/Snecma			f, h
CFM56-2-C1/-C3			DC-8 Super 71,72,73	
CFM56-2-C5/-C6			DC-8 Super 71,72,73	
CFM56-2B1 (F108-CF-100)		C-135FR KC-135R		
CFM56-2A2		E-3 KE-3 E-6		
CFM56-3-B1			B737-300, -500	
CFM56-3B-2			B737-300, -400	
CFM56-3C-1			737-400	
CFM56-5A2			A320	
CFM56-5A3			A320	
CFM56-5B1			A321	
CFM56-5B2			A321	
CFM56-5C-2			A340	
CFM56-5C-3			A340	
CFM56-5C-4			A340	

[a]Bold face engine model numbers are those for which speciated hydrocarbons were reported by the cited reference.

[b]Applications were taken from the most recent publication of Aviation Week & Space Technology, Specifications, McGraw-Hill Publications, New York, NY, March 1992.

[f]Spicer, C.W., M.W. Holdren, T.F. Lyon, and R.M. Riggin, Composition and Photochemical Reactivity of Turbine Engine Exhaust, ESL-TR-84-28, Tyndall Air Force Base, Florida, March 1984.

[g]Berry, D.A., M.W. Holdren, T.F. Lyon, R.M. Riggin, and C.W. Spicer, Turbine Engine Exhaust Hydrocarbon Analysis: Task 1 and 2, ESL-TR-82-43 Tyndall Air Force Base, Florida, June 1983.

[h]Aircraft Environmental Support Office (AESO), Toxic Organic Contaminants in the Exhaust of Gas Turbine Engines, Aircraft Environmental Support Office, Naval Aviation Depot, North Island, San Diego, California, AESO Report No. 12-90, September 1990.

emission indexes, calculation of emission indexes (with equations and computer listings included), examples of variations of gaseous emissions due to sampling method and fuel content, the use of emission indexes and emission rates, and summary tables of gaseous emissions from aircraft engines, with supporting AESO test data sheets.

The summary tables include three items. The first is a group of data giving the measured concentrations needed for the calculation of emission indexes and emission rates, although instrument interference correction factors are not included. The second item is a group of data giving the engine operating data and the emission indexes of carbon monoxide, carbon dioxide, oxides of nitrogen, and hydrocarbons. The third item is a group of data giving (1) the concentration of the oxides of nitrogen at an oxygen concentration of 3 percent, (2) the emission rate for each constituent in pounds/hour, (3) the combustion efficiency, and (4) the fuel/air ratio. The summary table includes also a reference to the original work.

The summary tables include engine emissions data obtained from measurements made by AESO, as well as data reported by other organizations, but is not all inclusive of all known engine emissions measurement data.

Finally, for those emission measurements performed by AESO, the supporting engine test data sheets for each engine are provided. These data sheets provide instrument interference coefficients, humidity data, molecular constants for the fuel, converter efficiency, calculated dry/semi-dry/wet concentrations of each exhaust gas constituent, calculated concentrations of water and nitrogen, calculated emissions of sulfur dioxide, the constant K (which allows conversion between wet and dry concentrations), engine exhaust temperature, power setting, engine speed, fuel flow rate, and other relevant information and documentation.

It is the opinion of AESO that the data summaries presented in this handbook are suitably representative for estimating emissions from other engines of the same type indicator and type numeral that have not been tested for emissions.

Because of concern and recognition that gas turbine engines are a source of toxic compounds, and to satisfy regulatory requirements to inventory these emissions from engine test cell facilities, AESO (1991)[9] prepared the report "Toxic Compounds in the Exhaust of Gas Turbine Engines." In this report "toxic compound" refers to those specific chemical compounds identified in the "Emission Inventory Criteria and Guidelines Regulation of the Air Toxics 'Hot Spots' Information and Assessment Act of 1987

(AB 2588)", and adopted with amendments by the State of California in 1990.

The purpose of this report is to present a method to estimate the amounts of toxic compounds in the exhaust of a gas turbine engine using (1) an emission index for the total hydrocarbons, (2) the percentage of each toxic compound in the total hydrocarbon mixture, and (3) a fuel flow rate. To facilitate these input requirements the report incorporated two previous AESO publications as appendices. AESO (1990)[10] was included as Appendix A, and is a collection of summary tables of gaseous and particulate emissions from aircraft engines, which had been published earlier (AESO Report No. 1-87). AESO (1990)[11] was included as Appendix B, and is a report detailing the treatment of toxic organic contaminants, as defined under the Emission Inventory Criteria and Guidelines Regulation of the California Air Toxics "Hot Spots" Information and Assessment Act. The report uses the findings developed by Spicer, et al (ESL-TR-84-28) to synthesize and derive a list of toxic organic constituents in gas turbine engine exhausts operating at idle power with JP-5 fuel. The synthesis, or conversion, is based on: computation of the percent contribution of each toxic species of interest to the total organic concentration, assumption that the ideal gas law and standard temperature and pressure, and carbon number.

The methodology for estimating emissions by species has been reported for nine engines. These engines and their usage in military or civil airframes are given in Table 4.

3.5 Total Hydrocarbon Emissions

Rubins, et al (1974)[12] reported the results of exhaust gas emission analysis on the PLT 27 gas turbine engine showing that the exhaust gases of this engine have a low content of unburned combustion products (i.e., hydrocarbons and carbon monoxide) down to idle power due to the high combustion efficiency of the engine. The combustion efficiency is 99.5 percent at idle and 99.9 percent above 10 percent of maximum-rated power. The PLT 27 was an advanced technology turboshaft engine rated at 2000 hp. Testing employed JP-4 fuel and three different fuel injector mechanisms. Total hydrocarbon emissions are compared to similar emissions for the T53-L-13A and T55-L-11A, for power settings of idle, intermediate 1, intermediate 2, 30 percent, 60 percent, 75 percent, and 100 percent.

The FAA Aircraft Engine Emissions Database (FAEED, 1991)[13] was created to provide a useful tool to support the analysis of emissions from aircraft engines for emissions inventories, analysis of fleet impacts, or other similar studies. The database was prepared to coincide with the publication of the

TABLE 4. ESTIMATED SPECIATED HYDROCARBON DATA FOR FIXED-WING AIRCRAFT

Engine[a]	Manufacturer	Application[b]		Ref.
		Military	Civilian	
F402	Rolls-Royce			c
F402-RR-408		AV-8B		
J52-P-6B	UT/Pratt & Whitney			c
J52-P-8B	UT/Pratt & Whitney			c
J52-P-8A, B		A-4, A-6		
J52-P-408	UT/Pratt & Whitney			c
J52-P-409		A-6, EA6B		
J79-GE-8D	General Electric			c
J79-GE-8		F-4B, RF-4B		
J79-GE-10B	General Electric			c
J79-GE-10, 17		F-4J, G, S		
J79-GE-15		F-4C,		
T64-GE-6B	General Electric			c
T64/P4D		C-27A	Alenia	
CT64-820-4		DHC-5C		
T56-A-16	GM/Allison			c
T56-A-14		P-3C		
T56-A-15		C-130H		
T56-A-425		E-2C, C-2A		
T56-A-427		E-2C		
T76-G-12A	Allied-Signal/Garrett			c
T76-G-10		OV-10A, D		

[a]Bold face engine model numbers are those for which speciated hydrocarbons were reported by the cited reference.

[b]Applications were taken from the most recent publication of Aviation Week & Space Technology, Specifications, McGraw-Hill Publications, New York, NY, March 1992.

[c]Aircraft Environmental Support Office (AESO), Toxic Compounds in the Exhaust of Gas Turbine Engines, Aircraft Environmental Support Office, Naval Aviation Depot, North Island, San Diego, California, AESO Report No. 3-91, May 1991.

Environmental Protection Agency's Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources and provides power settings, time in mode, fuel flow, and emission indices for hydrocarbons, carbon monoxide, nitrogen dioxide, and smoke number for each engine mode in two different listings: (1) the AP-42 Modal Emission Rates, and (2) the ICAO Exhaust Emissions Data Bank listing.

The EDMS-Microcomputer Pollution Model for Civilian Airports and Air Force Bases (Segal, 1991[14]) is an emissions and dispersion modeling system developed jointly by the FAA and the USAF for use in air quality assessments of airport sites and facilities. This model contains aircraft/engine/fuel files and associated emission rate files for carbon monoxide, hydrocarbons, NO_x, SO_x, and particulate matter, all by operating mode. The emission factors for the oxides and hydrocarbons are derived from test data supplied by the engine manufacturer for FAA certification. However, before using the models, one should verify the factors for each particular aircraft/engine combination (Wilcox, 1992[15]).

Garza (1992)[16] recently published the Aircraft Engine Emission Database System, which was an attempt to gather all U.S. military aircraft engine test data known to date. The resulting database contains all available emissions data, as well as other engine related information, the conditions under which the emissions tests were conducted, and references to the original data source. The user is cautioned to review carefully the emission results produced with this database, because some of the records were not reported in consistent units.

The database system allows the user to determine total hydrocarbon emissions, as well as carbon monoxide, carbon dioxide and nitrogen oxides (i.e., NO_X, NO, and NO_2) as mass concentration (ppm) and as emission rates (lb/1000 lbs of fuel or lbs/hr).

3.6 Helicopter Emissions From Total Hydrocarbon Species Estimates

No measured emissions by species were found for engines used in helicopters. However, the methodology described above for estimating emissions by species was applied to seven engine series used in helicopters. Table 3 lists the engines and shows their usage in military and/or civil airframes.

3.7 Health Effects

Our literature searches did not identify any published literature that related speciated hydrocarbon compound emissions from aircraft gas turbine engines, as a source category, specifically to the health effects thereof. Toxicity studies, or health effects studies, are usually not performed with respect to a source category--they are performed to characterize the suspected agent. The Clean Air Act amendments of 1990 contain provisions for air toxics that were not adequately addressed by the basic provisions of Section 112 of the 1970 or 1977 versions of the Act. The 1990 Air Act amendments require EPA to identify source categories that emit any of 189 identified air toxic compounds. A preliminary draft list of those source categories was published in 1991 of which turbine engine testing facilities were considered for inclusion based, in part, on speciation profiles of relatively poor quality ranking (i.e., the profile was based on measured data from a single facility or process, or from engineering estimates). Prior to the enactment of the 1990 amendments, the State of California enacted an air toxics law in 1988, the previously mentioned "Hot Spots" Information and Assessment Act of 1987 (AB 2588), which applied to any facility involved in the manufacture, formulation or release of any of some 330 published toxic substance. Under the provisions of AB2588 all facilities had to submit an emission inventory. The definitive study performed by Spicer, et al (1987)[17] was in fact performed to satisfy the requirements of AB2588.

The toxicity of most, if not all, of the compounds identified in jet engine exhausts, and named in the air toxics list of the Clean Air Act of 1990 or in the air toxics list of AB2588, are documented in RTECS.[18] In most cases RTECS also refers the reader to review articles discussing the toxicity studies.

TABLE 5. ESTIMATED SPECIATED HYDROCARBON DATA FOR ROTARY WING AIRCRAFT (HELICOPTERS)

Engine[a]	Manufacturer	Application[b]		Ref.
		Military	Civilian	
T58-GE-8F	General Electric	CH-46A UH-2C	K-888 SH-2F SH-3A	c
T58-GE-5 T58-GE-100 T58-GE-402			SH-3E HH-3E,-3F AH-61AA	
T58-GE-10		CH-46D UH-46D, F	Boeing 107 SH-3D, G, H	
T58-GE-16	General Electric	CH-46E		c
CT58-140			S-61 S-62	
T64-GE-6B	General Electric	CH-53A	S-65	c
T64-GE-7A		CH-53C HH-53C	S-65	
T64-GE-100		H-53 MH-53J TH-53A	S-65A	
T64-GE-413	General Electric	CH-53D	S-65	c
T64-GE-415	General Electric	RH-53D	S-65	c
T64-GE-415 T64-GE-416 T64-GE-416A		RH-53D CH-53D, E	S-65	
T64-GE-419		MH-53E CH-53E	S-65	
T400-CP-400	Pratt & Whitney	AH-1J UH-1N	Bell 209	c
T400-CP-402		AH-1T	Bell 209	

[a]Bold face engine model numbers are those for which speciated hydrocarbons were reported by the cited reference.

[b]Applications were taken from the most recent publication of Aviation Week & Space Technology, Specifications, McGraw-Hill Publications, New York, NY, March 1992.

[c]Aircraft Environmental Support Office (AESO), Toxic Compounds in the Exhaust of Gas Turbine Engines, Aircraft Environmental Support Office, Naval Aviation Depot, North Island, San Diego, California, AESO Report No. 3-91, May 1991.

4.0 CONCLUSIONS

Based on the information described in this report, the following conclusions are drawn. Note that distinctions are made among measured, estimated, and total hydrocarbon emissions.

1. Comprehensive exhaust emission measurements of air toxics by species were made by the military on seven turbine engine series (see Table 1). Two of the engine series (F101 and F110) were tested for organic constituents in or on particulate matter emissions.

2. A speciation program that uses engine and fuel characteristics has been used to estimate emissions of "California hot spot" toxics from a further 15 engine series (see Table 2).

3. Total hydrocarbon emissions have been measured for essentially all turbine engines in military or commercial use.

4. A computer program, given in reference 9 (AESO Report No. 3-91), has been developed that allows estimation of emissions by species or groups of species for common engine series. Approximately 95 percent of the mass of emissions expected to be found in engine exhausts are represented in the program. Input information includes hydrocarbon emissions, engine characteristics, and fuel type.

5. Health effects information was found in the Registry of Toxic Effects of Chemical Substances (reference 18) for individual species known to be in engine exhaust emissions; however, no information was found when searching under the topic of speciated aircraft engine emissions.

6. Of the 22 engine series for which species measurements were made or estimated (Conclusions 1 and 2), it appears that 8 are used in civil aircraft (5 fixed-wing basic airframe series, of which two are in declining use, and 9 rotary-wing basic airframes). All of the seven engine series for which exhaust gas species were measured appear to be in the current military inventory.

7. Emissions data, estimated by species from hydrocarbon measurements, exist for six helicopter engine series (see Table 3). All six series are used in military and civil helicopters. Measured emissions by species were not found for helicopter engines.

6. Many of the pertinent references (mostly military) found for this report were not listed in computer literature search data bases.

5.0 RECOMMENDATIONS

The following steps may be taken to determine current emission inventories and potential risk from aircraft engine toxic species emissions. The suggested estimations are expected to provide order-of-magnitude values.

1. Using the speciation methodology found in this literature search, estimate quantities of air toxics emitted by U.S. aircraft annually at an airport of choice. Aircraft landing and takeoff cycles would be included. These estimates would require obtaining information from the Federal Aviation Administration that would allow calculation of total movements at the airport by type of aircraft and engines. Meteorological information would be required to perform dispersion modeling in the airport vicinity.

2. Estimate health risks from emitted air toxics based on the maximum exposed individual or other criteria. One location for such estimates is a helicopter landing pad in a city area.

6.0 REFERENCES

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3. Spicer, C.W., M.W. Holdren, D.L. Smith, S.E. Miller, R.N. Smith, D.P. Hughes, Aircraft Emissions Characterization: F101 and F110 Engines, ESL-TR-89-13, Tyndall Air Force Base, Florida, March 1990.

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6. Berry, D.A., M.W. Holdren, T.F. Lyon, R.M. Riggin, and C.W. Spicer, Turbine Engine Exhaust Hydrocarbon Analysis: Task 1 and 2, ESL-TR-82-43 Tyndall Air Force Base, Florida, June 1983.

7. Aircraft Environmental Support Office(AESO), Gaseous Emissions From Aircraft Engines-A Handbook for the Calculation of Emission Indexes and Gaseous Emissions from Aircraft Engines, Aircraft Environmental Support Office, Naval Aviation Depot, North Island, California, AESO Report No. 1-87, September 1987.

8. Procedure for the Calculation of Basic Emission Parameters for Aircraft Turbine Engines, Aerospace Information Report: AIR 1533, SAE The Engineering Resource for Advanced Mobility, Warrendale, Pennsylvania, April 1982.

9. Aircraft Environmental Support Office (AESO), Toxic Compounds in the Exhaust of Gas Turbine Engines, Aircraft Environmental Support Office, Naval Aviation Depot, North Island, San Diego, California, AESO Report No. 3-91, May 1991.

10. Aircraft Environmental Support Office(AESO), Summary Tables of Gaseous and Particulate Emissions from Aircraft Engines, Aircraft Environmental Support Office, Naval Aviation Depot, North Island, San Diego, California, AESO Report No. 6-90, June 1990.

11. Aircraft Environmental Support Office (AESO), Toxic Organic Contaminants in the Exhaust of Gas Turbine Engines, Aircraft Environmental Support Office, Naval Aviation Depot, North Island, San Diego, California, AESO Report No. 12-90, September 1990.

12. Rubins, Phillip M., Edward Auerbach, Jochen A Deman, PLT 27 Gas Turbine Engine Exhaust Emission and Noise Measurements, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, Report No. USAAMRDL-TR-/4-61, September 1974.

13. Federal Aviation Agency, FAA Aircraft Engine Emissions Database (FAEED), Federal Aviation Agency, Office Of Environment and Energy, Washington, DC, Report No. AEE-100, November 26, 1991(Revised).

14. Segal, H. M., EDMS-Microcomputer Pollution Model for Civilian Airports and Air Force Bases: Users Guide, U.S. Department of Transportation, Federal Aviation Agency, Office of Environment and Energy, Washington, D.C., Report No. FAA-EE-91-3, June 1991 (co-published as U.S. Air Force Report No. ESL-TR-91-31).

15. Wilcox, R., Personal Communication, Environmental Protection Agency, Ann Arbor, Michigan, August 1992.

16. Garza, Julian, Aircraft Engine Emission Database System, Southwest Research Institute, San Antonio, Texas, August 1992. Prepared for: Naval Air Warfare Center, Aircraft Division, Trenton, New Jersey

17. Spicer, et al (see Ref. 4)

18. Registry of Toxic Effects of Chemical Substances (RTECS), National Institute for Occupational Safety and Health, Rockville, Maryland.TICS

APPENDIX A, SELECTED LITERATURE CITATIONS
(See Description in Section 3.0)

<u>EPA ONLINE LIBRARY SYSTEM (EPA/OLS)</u>

Main Title	NAVY TOXICITY STUDY OF SHALE AND PETROLEUM JP-5 AVIATION FUEL AND DIESEL FUEL MARINE. HEALTH EFFECTS INVEST. OF OIL SHALE DEVELOP.
Personal Author	COWAN MJ.
Call Number	582843

Main Title	Effect of Operating Variables on Pollutant Emissions from Aircraft Turbine Engine Combustors.
Personal Author	Grobma, J. ;
Corporate Author	National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
Year Published	1900
Call Number	N71-32484
Report Number	NASA-TM-X-67887

Main Title	Exhaust Emissions Test Airesearch Aircraft Propulsion and Auxiliary Power Gas Turbine Engines.
Corporate Author	AiResearch Mfg. Co. of Arizona, Phoenix.
Year Published	1900
Call Number	PB-204 920
Report Number	GT-8747-R; 0849;
Abstract	The report describes the test setup, procedure, and analysis of exhaust emissions measurement conducted on 32 commercial gas turbine engines comprised cf both on-board aircraft auxiliary power and aircraft propulsion production, overhaul, and development units. The units selected are currently active in commercial airline service and thus contribute to aircraft related pollution levels. The purpose of this test was to measure exhaust emissions from auxiliary power and small aircraft propulsion gas turbines engines to establish base levels of unburned hydrocarbons, carbon monoxide, carbon dioxide and oxides of nitrogen in current existing engine designs. In addition, a survey of engine duty cycles as related to normal customer operation in the field was made to determine a typical duty cycle and the corresponding estimated level of exhaust emissions produced. (Author)

Main Title	Sample Collection Techniques for Combustion Sources--Benzopyrene Determination.
Personal Author	Stenbur, Robert L. ; von Lehmde, Darryl J. ; Hangdbrauc, Robert P. ;
Corporate Author	Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.
Year Published	1900
Call Number	PB-214 953
Abstract	The extent to which benzo(a)pyrene and other polynuclear hydrocarbons are emitted to the atmosphere from some of the more commonly occurring suspect sources is currently being evaluated in a source sampling study by the Public Health Service. A first step in this study was the development of a technique for collecting samples from high temperature combustion and process gas streams in a manner which would assure retention of the hydrocarbon materials of interest. This paper reports the findings of a series of tests conducted to develop suitable methods for cooling the gas samples, to establish temperature requirements for the collected sample during the sampling period, and to evaluate wet versus dry collection techniques. (Author)

Main Title	Halogenated aliphatic, olefinic, cyclic, aromatic and aliphatic-aromatic hydrocarbon including the halogenated insecticides, their toxicity and potential dangers.
Personal Author	Von Oettingen, Wolfgang Felix
Publisher	U.S. Dept. of Health, Education, and Welfare, Public Health Service
Year Published	1955

Main Title	Collection and Assessment of Aircraft Emissions Base-Line Data Turboprop Engines (Allison T56-A-15.
Personal Author	Vaugh, J. M. ; Park, W. M. ; Johnso, S. E. J. ; Johnso, R. L. ;
Corporate Author	General Motors Corp., Indianapolis, Ind. Detroit Diesel Allison Div.
Year Published	1968
Call Number	PB-202 961
Report Number	DDAD-EDR-7200; EPA-CPA-68-04-0029;
Abstract	Exhaust emissions data were collected and evaluated from eleven new T56-A-15 military turboprop engines during their production-line performance evaluation. The normal production test schedule was used. Experimental data were analyzed by converting the concentration values measured for each engine to mass emissions over a landing and takeoff (LTO) cycle representative of a commercial flight with T56-type engines and then performing a statistical analysis to obtain mean and standard deviation values. (Author)

Main Title	Collection and Assessment of Aircraft Emissions.
Personal Author	Requerir, Jose F. ;
Corporate Author	Teledyne Continental Motors, Muskegon, Mich.
Year Published	1968
Call Number	PB-204 196
Report Number	TCM-635; EPA-68-04-0035;
Abstract	Five engines each of four different models of aircraft piston engines were tested for gaseous emissions (NO, HC, and CO). All of the engines were new engines. In addition, two tests were performed to determine the effect of installing the sample probe in different locations. One test was conducted to determine the effects of various air/fuel ratio settings on an engine at take-off power. (Author)

Main Title	Analysis of Aircraft Exhaust Emission Measurements: Statistics.
Corporate Author	Cornell Aeronautical Lab., Inc., Buffalo, N.Y.
Year Published	1968
Call Number	PB-204 869
Report Number	CAL-NA-5007-K-2; EPA-68-04-0040; 0848;
Abstract	Descriptive accounts are presented of statistical procedures which were applied to the analysis of mass emissions data as determined from aircraft exhaust emissions measurements. Results of these analyses are discussed, with an emphasis on the significance of the results within the context of the data base available. In essence, the purpose of the report is to isolate the causes or sources of both fixed and random contributions to the variability observed in the data and to estimate, wherever possible, the magnitudes of these contributions. Specific questions of broad interest are addressed and statistical inferences drawn with respect to these questions. (Author)

Main Title	Assessment of Aircraft Emission Control Technology.
Personal Author	Bastres, E. K. ; Bake, R. C. ; Robertso, C. F. ; Siege, R. D. ; Smit, G. E. ;
Corporate Author	Northern Research and Engineering Corp., Cambridge, Mass.
Year Published	1968
Call Number	PB-204 878
Report Number	NREC-1168-1; EPA-68-04-0011; 0850;
Abstract	The results are presented of an investigation which was aimed at providing information for establishing standards on emissions from aircraft activities. The program consisted of independent investigation of the following topics: Emission control by engine modification; Emission control by ground operations modification; Emission control by fuel modification; and Emission measurement. Engine modification control methods were identified through reviews of earlier work and through discussions with engine manufacturers. A list of specific control methods was formulated on the basis of preliminary analyses in which feasibility was indicated. The preliminary list of control methods was then subjected to more detailed analysis of control effectiveness and implementation costs. Ground operations modification control methods were evaluated in a similar manner.

Main Title	Analysis of Aircraft Exhaust Emission Measurements.
Personal Author	Bogda, Leonard ; McAdam, E. T. ;
Corporate Author	Cornell Aeronautical Lab., Inc., Buffalo, N.Y.
Year Published	1968
Call Number	PB-204 879
Report Number	CAL-NA-5007-K-1; EPA-68-04-0040; 0851;
Abstract	An account is presented of the analytical procedures and data processing techniques employed in translating field-measurement data of aircraft exhaust emissions into a form consistent with the needs for the promulgation of realistic standards. Pollutant mass emissions for carbon monoxide (CO) hydrocarbons (HC) and the oxides of nitrogen (NO(x)) are computed for an aircraft operational cycle comprised of the following modes: taxi/idle, take-off, climb out and approach. The calculations are for specific engine power (or thrust) settings for each mode as well as for specified times in mode. Numerical results are tabulated for each individual engine tested together with summaries obtained by aggregating engine data on a model basis. Data are presented for turboprop/turbine engines, light-utility piston engines and auxiliary power units. (Author)

Main Title	Study of Aircraft Powerplant Emissions.
Personal Author	Souza, Anthony F. ;
Corporate Author	Scott Research Labs., Inc., Plumsteadville, Pa.
Year Published	1968
Call Number	PB-207 107
Report Number	EPA-68-04-0037; 0916;
Abstract	Emissions from forty-two light aircraft piston engines and twenty-six military gas turbine engines have been measured and documented. Piston engine aircraft were leased from local general aviation suppliers and the engine exhaust emissions tested using a ten mode test cycle during a ground run-up. In addition crankcase ventilation emissions were measured on six engines and mass emission rates were calculated. Exhaust component concentrations and fuel consumption rates were measured at specified engine operating conditions. The exhaust analyzer readings were converted to pollutant concentrations and mass emission rates. The data were analyzed to determine engine-to-engine variations for each model engine, the effect of hot versus cold start, and the role of engine operating parameters. (Author)

Main Title	Collection and Assessment of Aircraft Emissions Baseline Data - Turbine Engines.
Personal Author	Nelso, A. W. ;
Corporate Author	Pratt and Whitney Aircraft, East Hartford, Conn.
Year Published	1968
Call Number	PB-207 321
Report Number	PWA-4339; EPA-68-04-0027; 0948;
Abstract	A report is presented of a study in which the design and fabrication of a multipoint sampling rake was completed. A check-out test of the rake using a JT9D experimental engine indicated that the exhaust emission sample obtained from the rake was very close to the average of the samples obtained from the individual probes located adjacent to the 12 rake sampling points. This probe was then used to sample the exhaust emission from an experimental engine of each of the JT3D, JT8D, and JT9D engine models, plus production engines. All of the mass emission results obtained during the program were subjected to a statistical analysis. The results of this analysis were then used in a hypothetical aircraft operational cycle. Measurements of smoke, dry particulates, total particulates, aldehydes, and olefins were also recorded. (Author)

Main Title	Potential Impact of Aircraft Emissions upon Air Quality.
Personal Author	Plat, M. ; Bake, R. C. ; Bastres, E. K. ; Chn, K. M. ; Siege, R. D. ;
Corporate Author	Northern Research and Engineering Corp., Cambridge, Mass.
Year Published	1968
Call Number	PB-208 950
Report Number	NREC-1167-1; DI-68-02-0085; 1085;
Abstract	The specific objectives were: to select representative airports for which detailed studies would be made of emissions and impact to determine aircraft emission factors and activity levels for the selected airports, to develop future projections of emission rates and their impact at the selected airports, and to determine emission rates and impact of unburned fuel resulting from fuel venting and other practices directly associated with aircraft operating cycles. The survey gives data on hydrocarbons, carbon monoxide, nitrogen oxides, particulates, SO2, and lead, all were in significant concentrations. Large reductions in concentrations of carbon monoxide, total hydrocarbons, nitrogen oxides, and particulates due to emissions of turbine-engine air-craft may be achieved by various control methods. However if this is not done, predictions presented show major pollution increases. (Author)

Main Title	Control of Emissions from Light Piston-Engine Aircraft.
Personal Author	Datwyle, W. F. ; Blatte, A. ; Hassa, S. T. ;
Corporate Author	Bendix Research Labs., Southfield, Mich.
Year Published	1968
Call Number	PB-230 900
Report Number	EPA-68-04-0045; 1521;
Abstract	The study was primarily of an experimental nature directed at observing and evaluating the results of applying existing automotive emission control techniques to aircraft piston engines. Attention was restricted to the emissions of unburned hydrocarbons, carbon monoxide, and oxides of nitrogen. Control techniques considered were those primarily used to reduce hydrocarbons and carbon monoxide, since the rich mixtures normally used in aircraft operation inherently lead to low levels of oxides of nitrogen. The general program approach was to select two typical engine configurations, design and implement selected emission control provisions, establish baseline emissions outputs for the standard engines, and determine the effect of the various emission control techniques and systems relative to the baseline values. A Continental 0-200 carbureted engine and a Lycoming IO-540 fuel-injection engine were selected for evaluation. The report describes the control approaches selected and tests conducted. Results are presented and discussed. Pertinent data are included for reference. (Modified author abstract).

Main Title	Nature and control of aircraft engine exhaust emissions; report of the Secretary of Health, Education, and Welfare to the United States Congress, pursuant to Public law 90-148, the Air quality act of 1967.
Corporate Author	National Air Pollution Control Administration.; United States. Dept. of Health, Education, and Welfare.; Northern Research and Engineering Corporation.
Publisher	U.S. Govt. Print. Off.,
Year Published	1969

Main Title	Study of Continuous Flow Combustion Systems for External Combustion Vehicle Powerplants.
Personal Author	Burklan, C. V. ; Le, W. B. ; Bah, G. ; Carlso, R. ;
Corporate Author	Marquardt Co., Van Nuys, Calif.
Year Published	1969
Call Number	PB-193 417
Report Number	PHS-CPA-22-69-128; 0574;
Abstract	Chemical kinetic studies were employed to better understand how and at what rate air pollutants are formed in an external combustion process. With this background, an experimental combustion test rig employing a recirculating step, staged burner was built. Tests were conducted with various liquid and vaporized liquid fuel injectors using aviation turbine fuel (Jet A) and 2,2,5-trimethylhexane. A wide range of fuel-air ratios were examined by individually controlling primary and secondary air flow rates. Fuel flows were varied from a maximum corresponding to a heat release of 500,000 BTU/hr to 1/30 of this value. Two runs were also made using gaseous methane fuel. The range of test variables were: injector configurations - pressure atomizing, vaporizing, 2nd vaporizing premixed; fuel flows from 0.15 to 4.5 gallons per hour; air flows from 3.4 to 103 standard cubic feet per minute; fuel equivalence ratio - primary from 0.53 to 1.59, and overall from 0.40 to 0.84; number of test conditions - 140; and cumulative combustion time - 22 hours. The tests demonstrated that gaseous and particulate emissions less than those established as the 1980 Federal Research goals can be achieved simultaneously in a high heat release, low pressure drop, burner configuration. The emission data measured at steady state conditions is compared to current and future emission goals for automobiles. (Author)

Main Title	Study of Exhaust Emissions from Reciprocating Aircraft Power Plants.
Corporate Author	Scott Research Labs., Inc., Plumsteadville, Pa.
Year Published	1969
Call Number	PB-197 627
Report Number	CPA-22-69-129; Scott-1136;
Abstract	The report documents the exhaust emission of light, piston engine aircraft and the phenomena of natural afterburning of the exhaust gases on contact with the ambient air. The approach used in the study was to measure the exhaust emissions of representative aircraft as they were flown in a normal manner. At the same time, the extent of afterburning was measured by sampling the exhaust plume downstream of the exhaust stack and comparing the plume composition, corrected for dilution, to the composition of the stack gases. The exhaust emissions from nine light aircraft were determined using a 9-mode takeoff-cruise-landing (TCL) (Author)

Main Title	Study of Jet Aircraft Emissions and Air Quality in the Vicinity of the Los Angeles International Airport.
Corporate Author	Los Angeles County Air Pollution Control District, Calif.
Year Published	1969
Call Number	PB-198 699
Report Number	CPA-22-69-137; 0662;
Abstract	The results of an investigation of the impact of jet aircraft operations on the air environment in the vicinity of a major air terminal are presented. The study, made at Los Angeles International Airport during the period of June 30, 1969, through November 18, 1970, had the following objectives: to determine total pollutant emissions from aircraft and ground operations at a major airport; to conduct exhaust measurements on the Pratt and Whitney JT4A and JT9D engines to complete the available exhaust emission data for gas turbine engines; to measure atmospheric concentrations of pollutants at ground level within and around a major airport; and, to determine the carbon monoxide exposure in an aircraft cabin during all ground operations. (APCO abstract)

Main Title	Gaseous Emissions from a Limited Sample of Military and Commercial Aircraft Turbine Engines.
Personal Author	Har, Charles T. ; Dietzman, Harry E. ; Springe, Karl J. ;
Corporate Author	Southwest Research Inst., San Antonio, Tex.
Year Published	1970
Call Number	PB-204 177
Report Number	SwRI-AR-816; EPA-EHSH-70-108;
Abstract	The objective of the aircraft turbine emissions measurement was to provide baseline gaseous emissions data, including hydrocarbons, carbon monoxide, carbon dioxide, and oxides of nitrogen, in a very limited time frame. Seventy-one tests were conducted in all, first on two types of military engines and later on six types of commercial engines. The work is documented, data are presented, and brief summaries and analyses are given.

Main Title	Air pollution by jet aircraft at Seattle-Tacoma airport.
Personal Author	Donaldson, Wallace R.
Publisher	Western Region, Weather Bureau,
Year Published	1970
OCLC Number	15490587

Main Title	STUDY OF JET AIRCRAFT EMISSIONS AND AIR QUALITY IN THE VICINITY OF THE LOS ANGELES INTERNATIONAL AIRPORT
Corporate Author	LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT CA
Year Published	1971
ID Number	00017842
Call Number	NTIS PB-198 699 MF
Report Number	CPA-22-69-137

Main Title	Jet aircraft emissions and air quality in the vicinity of the Los Angeles International Airport
Corporate Author	Los Angeles County Air Pollution District; Environmental Protection Agency
Year Published	1971
ID Number	00029126

Main Title	Exhaust emissions from gas turbine aircraft engines sub-council report February 1971 /
Corporate Author	National Industrial Pollution Control Council.
Publisher	For sale by the Superintendent of Documents, U.S. Government Printing Office,
Year Published	1971

Main Title	Hydrocarbon Pollutant Systems Study. Volume I. Stationary Sources, Effects, and Control.
Corporate Author	MSA Research Corp., Evans City, Pa.
Year Published	1971
Call Number	PB-219 073
Report Number	MSAR-72-233; EPA-71-12; 1499;
Abstract	The study goal was the development of a problem-solving R and D program for the control of hydrocarbon air pollutants from major stationary sources. Included in the report are identification, characterization and ranking of all significant stationary sources of hydrocarbon emissions; characterization of the effluent streams from the major sources of hydrocarbon emissions; evaluation, both technical and economic, of existing and developable technology for control of hydrocarbon emissions; and, development of R and D priorities and recommendations for a program that will ultimately lead to proven control hardware and technology.

Main Title	Field survey of emissions from aircraft turbine engines,
Personal Author	Cox, F. W.; Penn, F. W.; Chase, James O.
Publisher	U.S. Dept. of the Interior, Bureau of Mines
Year Published	1972

Main Title	Engine emissions; pollutant formation and measurement.
Personal Author	Springer, George S.; Patterson, Donald J.
Publisher	Plenum Press,
Year Published	1973

Main Title	Air Pollution: Control Techniques for Hydrocarbon and Organic Solvent Emissions from Stationary Sources.
Corporate Author	NATO Committee on the Challenges of Modern Society, Brussels (Belgium).;Environmental Protection Agency, Washington, D.C. Office of Air and Waste Management.;Research Triangle Inst., Durham, N.C.
Year Published	1973
Call Number	PB-240 577
Report Number	NATO/CCMS-19;
Abstract	Hydrocarbons and other organic matter in the atmosphere are known to have many adverse effects upon health and welfare, and reduction of emissions of these pollutants is of prime importance to any effective air pollution abatement program. This document has been prepared to summarize current information on organic air pollutants--sources and methods of control. Hydrocarbons and organic pollutants originate from a variety of sources, and the emissions vary widely in physical and chemical characteristics. The many agricultural, commercial, domestic, industrial, and municipal sources of these air pollutants are described individually in this document. The nature and quantities of the emissions from the various processes are discussed, and methods of control that have been successfully applied are listed. The control techniques described herein represent a broad spectrum of information from many engineering and other technical fields. A tabulation of emission factors from which overall emissions for the various sources can be estimated is presented.

Main Title	Aircraft emissions: impact on air quality and feasibility of control.
Corporate Author	United States. Environmental Protection Agency.
Year Published	1973
OCLC Number	00618747
Accession Number	164259

Main Title	Variability in Aircraft Turbine Engine Emission Measurements.
Personal Author	Souza, Anthony F. ; Reckner., Louis R. ;
Corporate Author	Scott Research Labs., Inc., Plumsteadville, Pa.; Environmental Protection Agency, Ann Arbor, Mich. Emission Control Technology Div.
Year Published	1974
Call Number	PB-251 155
Report Number	EPA-68-01-0443; EPA/460/3-74/006;
Abstract	The major objective of the program was the determination of the causes of variability in the measurement of aircraft turbine engine emissions. A state-of-the-art analysis system was designed and built according to the specifications of the contract. The analysis system was evaluated for reliability in the handling and accuracy in the measurement of emissions. Using the special analysis system, the variability in gas turbine engine emission measurements caused by the exhaust sample collection technique was studied using a Pratt and Whitney JT8D gas turbine engine. An exhaust gas mixing technique and a detailed exhaust gas cross section mapping technique were used for the verification of average exhaust emission concentrations. The variability in exhaust emission measurements produced by the direction of approach to a power setting and the effect of small variations in thrust and fuel flow on the measurement of mass emission rates are determined. All emission data collected are examined for the effect of ambient temperature and humidity.

Main Title	Influence of Aerodynamic Phenomena on Pollutant Formation in Combustion. Volume I. Experimental Results.
Personal Author	Bowman, Craig T. ; Cohen., Leonard S. ;
Corporate Author	United Technologies Research Center, East Hartford, Conn.;National Environmental Research Center, Research Triangle Park, N.C. Control Systems Lab.
Year Published	1975
Call Number	PB-245 344
Report Number	EPA-68-2-1092; EPA-ROAP-21BCC-014; EPA/650/2-75/061-a;
Abstract	The report gives results of the measurement of average concentration levels of NO, NO2, CO, and unburned hydrocarbons (THC) at the exhaust of an axisymmetric combustor over a significant range of operating conditions. In addition, it gives detailed species concentration, temperature, and velocity maps throughout the combustor for seven representative operating conditions. In the combustor, natural gas, a synthesized CH4/CO/H2 fuel, or vaporized propane issued through a central duct to mix and burn with an annular air stream in a 1.8 m long cylindrical duct. In a few tests, liquid propane was the fuel. Water-cooled probes were used to remove samples from the flow for on-line concentration analysis and to measure temperature, velocity, and flow direction. Elevated pressure and introduction of swirl, to the extent considered in the present experiments, create 'unmixedness' in the combustor flow field which in turn results in enhanced NO formation and consumption of hydrocarbons. Aerodynamic flame stabilization produces strong stirring which results in relatively low NO formation and hydrocarbon consumption rates.

Main Title	Vapor-Phase Organic Pollutants - Volatile Hydrocarbons and Oxidation Products.
Corporate Author	National Research Council, Washington, D.C. Panel on Vapor-Phase Organic Pollutants.;Health Effects Research Triangle Park, N.C.
Year Published	1975
Call Number	PB-249 357
Report Number	EPA-68-02-0542; EPA/600/1-75/005;
Abstract	This report concerns vapor-phase substances likely to be produced as community pollutants in sufficient amounts to affect health and well-being. Sources of vapor-phase organic pollutants are listed, including collection and sampling techniques and analytical methods. Possible mechanisms of formation of oxygenated organic hydrocarbon compounds in the atmosphere and of atmospheric reactions of oxides of nitrogen and sulfur are studied. Toxicologic, pathophysiologic, and epidemiologic information on vapor-phase organic pollutants is reviewed, their metabolism, and their effects on the total environment. Special attention is given to oxidized compounds, formaldehyde, ozone, and benzene. The report stresses the importance of oxidation reactions in the vapor-phase and the human health hazards produced from the more or less transient products of oxidation. The review of metabolism indicates that, although vapor-phase hydrocarbon pollutants are modified usually by enzymatic oxidation within mammalian systems from nonpolar to polar compounds (which are then excreted by the kidney), this sometimes occurs with the production of toxic intermediates. These reactions occur mostly in the liver and to a lesser extent in the kidney, intestine, and lung.

Main Title	HYDROCARBON EMISSIONS FROM JET ENGINES OPERATED AT SIMULATED. . .
Journal Title	ATMOS ENVIRON
Personal Author	KATZMAN H
Year Published	1975
Call Number	20060

Main Title	Determination of Aircraft Turbine Engine Particulates.
Personal Author	Johansen, Keith M. ; Kumm., Emerson L. ;
Corporate Author	AiResearch Mfg. Co. of Arizona, Phoenix.; Environmental Sciences Research Lab., Research Triangle Park, N.C.
Year Published	1975
Call Number	PB-251 247
Report Number	EPA-68-02-1236; EPA-ROAP-26ACU-31; EPA/650/2-75/055;
Abstract	This report describes research conducted to develop measurement techniques for particulate emissions from aircraft gas turbine engines. The ultimate goal was to establish optimum sampling procedures, parameters, devices, and instruments to use for measuring the mass of particulates emitted from gas turbines operating in the open atmosphere. On the basis of a series of tests with a turboprop engine and limited tests with turbofan engines, researchers concluded that: (1) accurate gravimetric measurements of engine particulate emissions can be made; (2) smoke number (reflectance) measurements do not correlate with gravimetric measurements of engine particulate emissions; and (3) as with smoke number measurements, it is difficult to relate gravimetric measurements of engine particulate emissions to ambient air quality standards.

Main Title	Aircraft Technology Assessment Interim Report on the Status of the Gas Turbine Program.
Personal Author	Munt, Richard ; Danielson, Eugene ; Deimen., James ;
Corporate Author	Environmental Protection Agency, Ann Arbor, Mich. Office of Mobile Source Air Pollution Control.
Year Published	1975
Call Number	PB-270 262
Abstract	This report is a brief summary of the status of the aircraft gas turbine technology assessment program. It is a compendium of the information and technical data received from all organizations, government and industrial, involved in efforts to reduce aircraft engine exhaust emissions. The technical data have been reduced and presented in the format that the EPA intends to use in making its assessment of the growth of low emissions technology in aircraft gas turbines. This actual assessment is, therefore, only a prelude to the assessment topic in that report. The information contained herein and the thrust of the assessment are directed towards compliance with the EPA 1979 standards for newly manufactured engines. Consideration of compliance with the 1981 standards for newly certified engines will be given in later reports as the technology advances.

Main Title	Emissions from Aircraft Fuel Nozzle Flames.
Personal Author	Tuttle, J. H. ; Shisler, R. A. ; Bilger, R. W. ; Mellor, A. M. ;
Corporate Author	Purdue Univ., Lafayette, IN. Combustion Lab.; Environmental Protection Agency, Ann Arbor, MI. Motor Vehicle Emission Lab.
Year Published	1975
Call Number	PB80-175938
Report Number	PURDU-CL-75-04; EPA-R-802650;
Abstract	Experimental emissions data from both internal flame and exhaust plane gathered in a simulated gas turbine primary zone at typical combustor operating conditions are analyzed in terms of the developed time parameters. Results indicate that, with a well atomized fuel spray, the large scale turbulent mixing controls the flame stoichiometry and hence the emissions characteristics. However as the fuel atomization becomes poorer, the flame structure is altered and emissions characteristics can be explained only by a combination of heterogeneous and homogeneous processes. Because CO and NOx emissions originate in separate regions of the flame, it was possible to alter the turbulent mixing properties of each region such that both CO and NOx were reduced.

Main Title	Analysis of Aircraft Emission Control Parameters.
Corporate Author	Environmental Protection Agency, Ann Arbor, MI. Standards Development and Support Branch.
Year Published	1975
Call Number	PB80-185796
Report Number	EPA-AA-AC-75-02;
Abstract	The impetus for this current analysis of the controlling parameter for aircraft emissions is the ongoing development of international emission regulations through the International Civil Aviation Organization (ICAO). The May 1975 meeting of the Aircraft Engine Emission Study Group (AEESG) of ICAO discussed various approaches to specifying the parameter for controlling aircraft emissions. Appendix A is the record of the meeting pertinent to the controlling parameter. During the May meeting, the viable parameters were narrowed to two basic approaches. Namely, the use of a measure of pollutants normalized by fuel flow and pollutants normalized by thrust or impulse. This report provides an analysis of the merits and disadvantages of these two different approaches.

Main Title	Alternative Derivations of the Standards for T5 (Supersonic Transport) Class Gas Turbine Aircraft Engines.
Corporate Author	Environmental Protection Agency, Ann Arbor, Mich. Standards Development and Support Branch.
Year Published	1976
Call Number	PB-270 892
Report Number	AC-76-01;
Abstract	This document contains five alternative approaches to the development of standards for emissions from T5 class aircraft engines. Four of these approaches attempt to comply with EPA's earlier stated intention to set standards as stated in the Preamble to Aircraft Standards, FR Vol. 38 No. 136 19088. Three of these approaches are found faulty by not imposing on the T5 class 'the same types of combustor design technology, as will be required of subsonic aircraft'. The fourth approach satisfactorily imposes the implementation of a common, acceptable technology. A fifth approach is investigated which attempts to set standards which are compatible with the constraint of requiring compliance in 1979 or shortly thereafter.

Main Title	Sources of Variability and Inaccuracies in Aircraft Gas Turbine Emission Measurements.
Corporate Author	Environmental Protection Agency, Ann Arbor, Mich. Standards Development and Support Branch.
Year Published	1976
Call Number	PB-270 898
Report Number	AC-76-02;
Abstract	Variability and inaccuracies in aircraft gas turbine emission measurements caused by calibration gases, instrument precision, sampling errors, engine setting precision, and ambient condition effects continue to be of major concern. Understanding and/or resolution of these factors is critical to the development of a unified measurement procedure. This report details and provides analysis of the various factors contributing to emission measurement inaccuracy. Discussion is presented for all major sections and components of the emission sampling system.

Main Title	Determination of Effects of Ambient Conditions on Aircraft Engine Emissions Engine Testing - GTCP 85 APU, TPE 331 Turboprop. Volume 1.
Personal Author	Slogar., Gerrick A. ;
Corporate Author	AiResearch Mfg. Co. of Arizona, Phoenix.; Environmental Protection Agency, Ann Arbor, Mich. Emission Control Technology Div.
Year Published	1976
Call Number	PB-252 825
Report Number	75-311636-1; EPA-68-03-2156; EPA/460/3-76/009a;
Abstract	Under Environmental Protection Agency contract number 58-03-2156, AiResearch Manufacturing Company of Arizona, a Division of the Garrett Corporation, conducted full scale engine tests on a GTCP85-98CK Auxiliary Power Unit and a TPE331-5-251M Turboprop engine. The purpose of this program was to measure exhaust emission of HC, CO, CO2, NOx, and smoke at controlled (temperature, humidity, and pressure) engine inlet conditions. This data along with other available data will provide the data base for the determination of the effects of ambient conditions on gas turbine engines.

Main Title	Air Pollution Assessment of Ethylene Dichloride.
Personal Author	Johns., R. ;
Corporate Author	Mitre Corp., McLean, Va.;Environmental Protection Agency, Research Triangle Park, N.C. Office of Air Quality Planning and Standards.
Year Published	1976
Call Number	PB-256 733
Report Number	MTR-7164; EPA-68-02-1495;
Abstract	Ethylene dichloride, a chlorinated hydrocarbon, is primarily used as an intermediate during the production of vinyl chloride and other commertially valuable compounds. The characteristic water solubility and vapor pressure of ethylene dichloride indicate that this compound will tend to persist in the hydrosphere and lithosphere; while its slow activity with peroxide radicals and ozone indicates atmospheric persistence as well. Industrial exposure is limited by Occupational Safety and Health regulations to 200 mg/cum (50 ppm). Ambient atmospheric measurements are not readily available. Inhalation of ethylene dichloride during acute exposure has been shown to produce central nervous system disorders as well as pathological effects in the liver, kidneys, and adrenals of humans, while chronic human exposure produces similar results. The no-lasting-effect level is quite high (1000 ppm for 1 hour and 3000 ppm for 6 minutes) indicating that detrimental exposure levels would have to be much greater. Although the compound does not appear to pose a significant environmental hazard, little information is available for assessment of potential long-term low level effects. As a result ethylene dichloride cannot be considered innocuous until additional health data is accumulated.

Main Title	Characteristic Time Correlation of Emissions from Conventional Aircraft Type Flames.
Personal Author	Tuttle, J. H. ; Colket, M. B. ; Mellor., A. M. ;
Corporate Author	Purdue Univ., Lafayette, Ind. Combustion Lab.; Environmental Protection Agency, Washington, D.C.
Year Published	1976
Call Number	PB-258 269
Report Number	PURDU-CL-76-05; EPA-R-802650-02;
Abstract	The overall combustion process occurring within a liquid spray fueled burner is analyzed in terms of the ongoing dominant subprocesses, with particular emphasis on those subprocesses deemed most critical to pollutant emissions. Liquid fuel evaporation, turbulent mixing, and chemical reaction are each considered separately and are characterized by time scales which typify the importance of each subprocess. An axisymmetric burner consisting of a flame stabilized in the wake of a disc with a liquid fuel spray injected into the wake region from the center of the disc is considered experimentally. The basic flame structure behind the disc is composed of a hollow reaction region (shear layer) along the boundary between the recirculation zone and the free stream. Guided by the model of the flame structure, the developed characteristic times are combined to form burner output correlating parameters. The success of these parameters is demonstrated by the correlation of both carbon monoxide and oxides of nitrogen exhaust emissions from the disc burner for various geometries, a wide range of burner operating conditions, and two non-similar fuels. The developed characteristic time model is extended to a conventional gas turbine combustor, GT-309. The model predicts the effect of changes in both combustor inlet conditions and combustor geometry on exhaust emissions and is used to demonstrate the design of a low NOx burner of the GT-309 class.

Main Title	Assessment of Cyclohexanone as a Potential Air Pollution Problem. Volume VII.
Personal Author	Patterson, Robert M. ; Bornstein, Mark I. ; Garshick., Eric ;
Corporate Author	GCA Corp., Bedford, Mass. GCA Technology Div.; Environmental Protection Agency, Research Triangle Park, N.C.
Year Published	1976
Call Number	PB-258 359
Report Number	GCA-TR-75-32-G(7); EPA-68-02-1337;
Abstract	Cyclohexanone is a colorless, slightly volatile liquid with an odor similar to acetone and peppermint. It is chemically stable and is manufactured mainly by catalytic dehydration of cyclohexanol. It is used extensively in the production of nylon and adipic acid, and it is also used as a solvent and degreaser. Cyclohexanone is a strong irritant and a narcotic agent at high concentrations, although concentrations producing such effects are unlikely to occur due to the low volatility of cyclohexanone. Although emission controls specifically for cyclohexanone are not reported, two types of controls are used extensively by the chemical industry to control hydrocarbon emissions. These are vapor recovery and incineration. Control by adsorption on activated charcoal is used when recovery is economically desirable. Based on the results of the health effects research presented in this report, and the ambient concentration estimates, it appears that cyclohexanone as an air pollutant does not pose a threat to the health of the general population. In addition, cyclohexanone does not appear to pose other environmental insults which would warrant further investigation or restriction of its use at the present time.

Main Title	Assessment of Ortho-Xylene as a Potential Air Pollution Problem. Volume X.
Personal Author	Patterson, Robert M. ; Bornstein, Mark I. ; Garshick., Eric ;
Corporate Author	GCA Corp., Bedford, Mass. GCA Technology Div.; Environmental Protection Agency, Research Triangle Park, N.C.
Year Published	1976
Call Number	PB-258 362
Report Number	GCA-TR-75-32-G(10); EPA-68-02-1337;
Abstract	Xylene is a colorless, flammable liquid having an aromatic odor similar to that of benzene and toluene. There are three isomers of xylene: ortho-, meta-, and para-xylene. Data linking ortho-xylene exposure with health effects are lacking, due to the almost always concomitant benzene and toluene. Ortho-xylene is an irritant and narcotic at high concentrations, producing effects similar to alcohol intoxication. The primary emission sources in descending order are mixed xylene solvent usage, mixed xylene production, ortho-xylene production and solvent usage, and bulk storage. Total emissions are estimated to have been about 184 million pounds in 1974. Although emission controls specifically for ortho-xylene are not reported, two types of controls are used extensively by the chemical industry to control hydrocarbon emissions. These are vapor recovery and incineration. Control by adsorption on activated charcoal is used when recovery is economically desirable. Based on the results of the health effects research presented in this report, and the ambient concentration estimates, it appears that ortho-xylene as an air pollutant does not pose a threat to the health of the general population. In addition, ortho-xylene does not appear to pose other environmental insults which would warrant further investigation or restriction of its use at the present time.

Main Title	Determination of effects of ambient conditions on aircraft engine emissions engine testing
Personal Author	Slogar, G A
Publisher	Environmental Protection Agency, Office of Air and Waste Management, Office of Mobile Source Air Pollution Control, Emission Control Technology Division ;
Year Published	1976

Main Title	Aircraft Technology Assessment Status of the Gas Turbine Program.
Personal Author	Munt, Richard ; Danielson., Eugene ;
Corporate Author	Environmental Protection Agency, Ann Arbor, Mich. Emission Control Technology Div.
Year Published	1976
Call Number	PB-277 351
Report Number	EPA/460/3-76/036;
Abstract	This report details the advances that have been made in the control of aircraft gas turbine engine emissions. Two technologies of differing complexities have evolved. The success of the first, which controls only hydrocarbons and carbon monoxide, is attributable to innovations in engine operation, the fuel injection system, and the airflow patterns within the combustor. The simplicity of this system gives it wide applicability. The second technology, capable of controlling oxides of nitrogen, in addition to HC and CO, uses exotic methods of fuel preparation and multiple zones of combustion. A table, which follows the report, summarizes the EPA technical staff's assessment of the prospects of each engine meeting the levels specified in the 1979 standards, based on manufacturers' data. Control strategies for HC and CO should be ready for implementation by 1979-1980, but, due to the complexity of the oxide of nitrogen control systems, and the fact that requisite levels of technology are currently found only in some of the largest T2 12 class engines, the practicality of implementation in T1 and APU classes by 1982 is questioned.

Main Title	Aircraft Emission Factors.
Personal Author	Pace., Robert G. ;
Corporate Author	Environmental Protection Agency, Ann Arbor, Mich. Standards Development and Support Branch.
Year Published	1977
Call Number	PB-275 067
Report Number	AC-77-03;
Abstract	In order to perform useful air quality analysis it is necessary to have the most accurate emission factor data available. This report provides updated aircraft engine emission factors and a sample of the calculation methodology used in obtaining these numbers. Modal emission factors have been calculated for a number of gas turbine and piston aircraft engines. Emission factors per aircraft per landing take-off cycle have been calculated for representative aircraft- engine combinations. This group includes commercial jet transports, business jets, turboprops and general aviation piston aircraft.

Main Title	Cost-Effectiveness Analysis of the Proposed Revisions in the Exhaust Emission Standards for New and In-Use Gas Turbine Aircraft Engines Based on Industry Submittals.
Personal Author	Wilcox, Richard S. ; Munt., Richard ;
Corporate Author	Environmental Protection Agency, Ann Arbor, Mich. Standards Development and Support Branch.
Year Published	1977
Call Number	PB-276 508
Report Number	AC-77-02;
Abstract	This report provides analysis of several control strategies. Those studied were: the control of newly manufactured gas turbine engines in 1981 for HC and CO only; retrofit of in-use gas turbine engines in 1985 for HC and CO only; and the control of newly manufactured gas turbine engines in 1984 for HC, CO, and NOx. The cost information is incomplete and poorly documented due to a lack of detailed data. Additional error was introduced by the fact that the nature of the study demanded that assumptions and predictions be made in an attempt to ascertain future facts. The above considerations aside, the cost-effectiveness figures generated by this analysis represent EPA's best estimate of the costs imposed by the control strategies under consideration, based on industry submittals. For the purposes of this study, the JT8D was assumed to be out of production by 1984. This is no longer true and the planned growth version of this engine will be examined in a later report.

Main Title	Aircraft Emissions at Selected Airports, 1972-1985.
Personal Author	Deiman, James M. ;
Corporate Author	Environmental Protection Agency, Ann Arbor, MI. Standards Development and Support Branch.
Year Published	1977
Call Number	PB-286 145
Report Number	AC-77-01;
Abstract	This report presents airport vicinity aircraft emissions data for HC, CO and NOx at selected commercial and general aviation airports. The data represents an updating of calculated aircraft emissions for recent years and estimates of future aircraft emissions. Operations by individual aircraft models are scrutinized in detail. Breakdowns of operations by air carriers, air taxis, general aviation and auxiliary power units are included and the emissions from each are summed to provide estimates of total pollutants dispersed. Despite a general trend toward more operations, the total emissions at the commercial airports decrease as a result of a changing fleet mix with more modern engines and the advent of promulgated and proposed regulatory standards. With increased operations at general aviation airports, emissions will continue to increase without the imposition of regulatory standards because uncontrolled modern engines emit substantially the same pollutants as older piston engine designs.

Main Title	Determination of Effects on Ambient Conditions on Aircraft Engine Emissions. ALF 502 Combustor Rig and Engine Verification Test.
Personal Author	Trembley, Jr, H. F. ;
Corporate Author	Avco Lycoming Div., Stratford, CT.;Environmental Protection Agency, Ann Arbor, MI. Emission Control Technology Div.
Year Published	1977
Call Number	PB-290 326
Report Number	LYC-77-54; EPA-68-03-2383; EPA/460/3-77/017;
Abstract	A program was conducted for the purpose of determining the effects of ambient temperature, humidity, and pressure on the emissions of hydrocarbons, carbon monoxide, oxides of nitrogen, and smoke. The approach involved the performance of two tasks. Task I was to gather data through Lycoming ALF 502 combustor rig testing under controlled simulated inlet conditions; Task II was to test a full-scale ALF 502 engine over a range of uncontrolled ambient conditions to verify the rig test data. These data will be part of a data base collected by the EPA for the development of correction factors for gas turbine engine emissions.

Main Title	Determination of Effects of Ambient Conditions on Aircraft Engine Emissions: ALF 502 Combustor Rig Testing and Engine Verification Test.
Personal Author	Trembley, Jr., H. F. ; Cackette, Thomas ;
Corporate Author	Avco Lycoming Engine Group, Stratford, CT. Stratford Div.;Environmental Protection Agency, Ann Arbor, MI. Emission Control Technology Div.
Year Published	1977
Call Number	PB82-238668
Report Number	LYC-77-54; EPA-68-03-2383; EPA-460/3-77-017;
Abstract	A program was conducted by Avco Lycoming Engine Group for the purpose of determining the effects of ambient temperature, humidity, and pressure on the emissions of hydrocarbons, carbon monoxide, oxides of nitrogen, and smoke. The approach involved the performance of two tasks. Task I was to gather data through Lycoming ALF 502 combustor rig testing under controlled simulated inlet conditions; Task II was to test a full-scale ALF 502 engine over a range of uncontrolled ambient conditions to verify the rig test data.

Main Title	Determination of Effects of Ambient Conditions on Aircraft Engine Emissions: Data Analysis and Correction Factor Generation.
Personal Author	Donovan, Paul J. ; Fairchild, William R. ; Graves, Kenneth W. ;
Corporate Author	Calspan Corp., Buffalo, NY.;Environmental Protection Agency, Ann Arbor, MI. Emission Control Technology Div.
Year Published	1977
Call Number	PB82-229360
Report Number	EPA-68-03-2159; EPA-460/3-77-019;
Abstract	This report presents a set of correction factors for variations in turbine aircraft HC, CO, NOX and smoke emissions due to non-standard day ambient temperature, pressure and humidity developed for the United States Environmental Protection Agency, Ann Arbor, Michigan. These correction factors are based on data from three EPA-sponsored full-scale engine tests, two EPA-sponsored combustor rig tests, and additional data solicited from industry sources. Key correlating parameters in this analysis were combustor inlet temperature, combustor inlet pressure, and ambient humidity. The correction factors have been developed using a multiple least squares regression analysis approach using functional emissions models based upon theoretical considerations and an extensive review of current ambient effects literature. Emphasis has been placed upon relating correction factor coefficients within a general engine class to various operating characteristics of each individual engine.

Main Title	Review of Past Studies Addressing the Potential Impact of CO, HC, and NOx Emissions from Commercial Aircraft on Air Quality.
Personal Author	Lorang, Philip ;
Corporate Author	Environmental Protection Agency, Ann Arbor, MI. Standards Development and Support Branch.
Year Published	1978
Call Number	PB-286 421
Report Number	AC-78-03;
Abstract	Since 1973, EPA has monitored the progress of technology needed to meet the existing air quality standards for aircraft engine emissions, and reviewed the impact of various classes of aircraft on ambient air quality. As a result, there is now in draft form an NPRM to amend the existing standards. During the preparation of the draft NPRM, several commenters questioned the air quality justifications for certain standards. This report is partial documentation of EPA's review of the past air quality studies, and also a review of air quality justifications for the commercial aircraft emission standards contained in the NPRM.

Main Title	Economic Impact of Revised Gaseous Emission Regulations for Commercial Aircraft Engines.
Personal Author	Day, C. F. ; Bertrand, H. E. ;
Corporate Author	Logistics Management Inst., Washington, DC.; Environmental Protection Agency, Ann Arbor, MI.
Year Published	1978
Call Number	PB-286 772
Report Number	EPA-68-01-4647;
Abstract	The EPA has proposed the revision of the gaseous emission regulations first promulgated in 1973 (40 CFR Part 87) for several classes of aircraft engines. A draft notice of Proposed Rule Making (NPRM) was prepared and circulated informally outside EPA in the late summer of 1977. This report presents the results of an economic impact analysis of the proposed standards as they apply to commercial aircraft engines.

Main Title	U.S. Aircraft Fleet Projection and Engine Inventory to Year 2000.
Personal Author	Munt., Richard W. ;
Corporate Author	Environmental Protection Agency, Ann Arbor, Mich. Standards Development and Support Branch.
Year Published	1978
Call Number	PB-285 189
Report Number	AC-78-02 ;EPA/TSR/AC-78/02;
Abstract	This report provides a forecast of the number of aircraft gas turbine engines which must comply with the proposed revisions to the EPA emissions standards. In providing this, it also supplies an aircraft forecast (useful if engines are changed on a given airframe) and a general engine forecast (useful if other revisions are proposed). This information may be used directly to obtain estimates of the total impact of various standards and implementation dates and more importantly, to obtain estimates of the total cost and cost effectiveness of the standards.

Main Title	Evaluation of emission control strategies for airfield operations at the Los Angeles and San Francisco international airports
Personal Author	Gelinas, C. Gary.
Publisher	AeroVironment,
Year Published	1978
OCLC Number	20321862

Main Title	Air Pollutant Emission Factors for Military and Civil Aircraft.
Personal Author	Sears, D. Richard ;
Corporate Author	Lockheed Missiles and Space Co., Inc., Huntsville, AL. Huntsville Research and Engineering Center.; Environmental Protection Agency, Research Triangle Park, NC. Office of Air Quality Planning and Standards.
Year Published	1978
Call Number	PB-292 520
Report Number	LMSC-HREC-TR-D568208; EPA-68-02-2614; EPA/450/3-78/117;
Abstract	Using data supplied by the U.S. Navy, U.S. Air Force, USEPA Office of Mobile Source Air Pollution Control, as well as published information, tables of military aircraft fuel characteristics, aircraft classifications, military and civil times in mode, engine modal emission rates, and aircraft emission factors per landing-takeoff cycle are calculated and compiled. The data encompass 59 engines and 89 aircraft. Additional discussion includes information related to benzo(a)pyrene emissions and to hydrocarbon emissions (volatile organic) with potential to produce photochemical oxidant.

Main Title	Investigations of Selected Environmental Pollutants: 1,2-Dichloroethane.
Personal Author	Drury, John S. ; Hammons., Anna S. ;
Corporate Author	Oak Ridge National Lab., TN.;Environmental Protection Agency, Washington, DC. Office of Toxic Substances.;Department of Energy, Washington, DC.
Year Published	1979
Call Number	PB-295 865
Report Number	ORNL/EIS-148; W-7405-eng-26; EPA/560/2-78/006;
Abstract	This study is a comprehensive, multidisciplinary review of the health and environmental effects of 1, 2-dichloroethane. Other pertinent aspects such as production, use, methods of analysis, and regulatory restrictions are also discussed. Approximately 250 references are cited. 1, 2-Dichloroethane is manufactured in greater tonnage than any other chlorinated organic compound; in 1977 nearly 5 million metric tons was synthesized in the United States. It is used primarily as a raw material in the production of vinyl chloride monomer and a few other chlorinated organic compounds. The environment is exposed to this chlorinated hydrocarbon primarily through manufacturing losses. Smaller exposures occur through dispersive uses, such as grain fumigations and application of paints and other coatings, and through storage, distribution, and waste disposal operations. Concentrations of 1,2-dichloroethane in environmental air and water distant from point sources are small--on the order of parts per billion or less. Concentrations in the environment near point sources are unknown. 1,2-Dichloroethane is toxic to humans, other vertebrates and invertebrates, plants, and microorganisms. It is an established carcinogen in rats and mice exposed by oral intubation and is a weak mutagen in some bacteria and certain grains.

Main Title	Determination of the Effects of Ambient Conditions on CFM56 Aircraft Engine Emissions.
Personal Author	Lyon, T. F. ; Dodds, W. J. ; Bahr., D. W. ;
Corporate Author	General Electric Co., Cincinnati, OH. Aircraft Engine Group.;Environmental Protection Agency, Ann Arbor, MI. Standards Development and Support Branch.
Year Published	1979
Call Number	PB80-138597
Report Number	R79AEG632; EPA-68-03-2388; EPA-460/3-79/011;
Abstract	It has been known that variations in ambient temperature, pressure, and humidity can have significant effects on measured emissions levels. Although the need to account for variation in ambient conditions is generally recognized, and several studies have attempted to establish more or less universal correction factors, there is no widely accepted procedure for the correction of emissions measurements to reference-day ambient conditions. A current program by the EPA is to establish a wide data base from which procedures for correction of measured emissions levels to reference day conditions can be developed. To establish this data base, EPA contracted with three engine manufacturers to make tests under controlled ambient conditions. To supplement these data, industry and other government agencies were requested to submit data that could be used in establishing an acceptable correction procedure. The CFM 56 engine was selected for this study because it is representative of the next engine of highly efficient, large turbofans which will be in production when EPA gaseous emissions standards first become effective in the early 1980's.

Main Title	Evaluation of HC (Hydrocarbon) Control Strategies for General Aviation Piston Engines.
Personal Author	Wilcox, Richard S. ;
Corporate Author	Environmental Protection Agency, Ann Arbor, MI. Standards Development and Support Branch.
Year Published	1979
Call Number	PB80-155393
Report Number	EPA-AA-SDSB-79-17;
Abstract	In support of the current final rulemaking action for aircraft emission standards, the cost effectiveness of controlling hydrocarbon (HC) exhaust emissions from general aviation piston-powered aircraft (P1) is evaluated. Houtman previously evaluated the cost effectiveness of controlling this source for HC and carbon monoxide (CO). Recent analyses by Jordan and FAA have indicated that these aircraft are not major contributors to violations of the National Ambient Air Quality Standard for CO which adversely affect the public health and welfare. Although HC emissions from general aviation are also small when compared to many other sources, the oxidant problem is so widespread that all reasonable controls should be implemented. Based on this premise, several potentially cost-effective control strategies for these aircraft are evaluated to determine if reductions in HC from general aviation piston-powered aircraft are justified.

Main Title	Chemical Composition of Exhaust Particles from Gas Turbine Engines.
Personal Author	Robertson, D. J. ; Elwood, J. H. ; Groth, R. H. ;
Corporate Author	Pratt and Whitney Aircraft Group, East Hartford, CT. Commercial Products Div.;Environmental Sciences Research Lab., Research Triangle Park, NC.
Year Published	1979
Call Number	PB-292 380
Report Number	EPA-68-02-2458; EPA/600/2-79/041;
Abstract	A program was conducted to chemically characterize particulate emissions from a current technology, high population, gas turbine engine. Attention was focused on polynuclear aromatic compounds, phenols, nitrosamines and total organics. Polynuclear aromatic hydrocarbons (PAH) were determined by HPLC, GC/MS and NMR techniques. Phenols and nitrosamines were isolated and then measured by gas chromatographic methods utilizing flame ionization detection and nitrogen detection. Total organics were determined by a backflush chromatographic procedure. The particulate matter was collected using a high capacity pumping system incorporating 293 mm diameter Teflon filters through which was passed up to 43 cu m of exhaust gas. Extraction of the organic matter was performed in a Soxhlet extractor using hexane. The engine was operated at idle, approach, climb and take-off power settings with low sulfur (0.007%S) and high sulfur (0.25%S) fuels. Most of the PAH were small 3-to-4 fused ring species. No nitrosamines were found and except in a few cases, at low levels, no phenols. PAH and total organic levels decreased with increasing power setting and were more concentrated in the exhaust from the low sulfur fuel. Less than 1% of the organic matter emitted from the engine was adsorbed on the particulate matter.

Main Title	Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds. Volume II: Emission Inventory Requirements for Photochemical Air Quality Simulation Models.
Corporate Author	Environmental Protection Agency, Research Triangle Park, NC. Monitoring and Data Analysis Div.
Year Published	1979
Call Number	PB80-202229
Report Number	EPA-450/4-79-018;
Abstract	This is a companion document to Volume I, which describes procedures for compiling the annual countywide inventory of volatile organic compound (VOC) emissions. Volume II describes procedures for converting the annual countywide emission inventory to the detailed inventory needed for photochemical models. The detailed inventory contains hourly gridded emissions (by species class for VOC and NOx) for a typical weekday during the oxidant season.

Main Title	Health Assessment Document for Polycyclic Organic Matter.
Personal Author	Santodonato, Joseph ; Howard, Phillip ; Basu, Dipak ; Lande, Sheldon ; Selkirk, James K. ;
Corporate Author	Syracuse Univ. Research Corp., NY.;Environmental Protection Agency, Research Triangle Park, NC. Environmental Criteria and Assessment Office.
Year Published	1979
Call Number	PB82-186792
Report Number	EPA-68-01-2800; EPA-600/9-79-008;
Abstract	The document responds to Section 122 of the Clean Air Act as Amended August 1977, which requires the Administrator to decide whether atmospheric emissions of polycyclic organic matter (POM) potentially endanger public health. This document reviews POM data on chemical and physical properties, atmospheric forms, atmospheric fate and transport, measurement techniques, ambient levels, toxicology, occupational health, and epidemiology. Polycyclic aromatic hydrocarbons (PAH's), such as the carcinogen benzo(a)pyrene (BaP), and their neutral nitrogen analogs are the two POM chemical groups occurring most frequently in ambient air. The major environmental sources of POM's appear to be the combustion or pyrolysis of materials containing carbon and hydrogen. There is general agreement that POM compounds are associated with suspended particulate matter from both mobile and stationary sources, principally respirable particles. Available monitoring data suggest that many POM compounds associated with particulate matter probably are stable in ambient air for several days. The major health concern over exposure to POM's is their carcinogenicity. POM's gain ready access to the body's circulation either by inhalation, ingestion, or skin contact. Although it cannot be stated unequivocally that any POM's are human carcinogens, several of these compounds are among the more potent animal carcinogens known.

Main Title	Quantitative Analysis of Polynuclear Aromatic Hydrocarbons in Liquid Fuels.
Personal Author	Parr, Jerry L. ;
Corporate Author	Radian Corp., Austin, TX.;Environmental Sciences Research Lab., Research Triangle Park, NC.
Year Published	1980
Call Number	PB80-187388
Report Number	EPA-68-02-2466; EPA-600/2-80-069;
Abstract	Polynuclear aromatic hydrocarbons (PNAs), formed in combustion processes with liquid hydrocarbon fuels, contribute to mobile source exhaust emissions. Because correlation between PNA levels in automobile exhaust and pre-existent PNAs in fuel has been demonstrated in previous work, a quantitative analysis of 12 individual polynuclear aromatic hydrocarbons present in various aircraft turbine, diesel, and gasoline test fuels was determined in this project. The PNAs included phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, triphenylene, benzo(a)pyrene, benzo(e)pyrene, benzo(g,h,i)perylene, coronene and anthanthrene. The fuel samples were analyzed by combined gas chromatography/mass spectrometry (GC-MS) after a preliminary isolation/concentration scheme. Liquid crystal chromatographic columns were employed to resolve isomeric PNAs. The results indicated that anthanthrene and coronene were not detected in any of the samples analyzed.

Main Title	Compilation of Air Pollutant Emission Factors, Third Edition (Including Supplements 1-7). Supplement No. 10.
Corporate Author	Environmental Protection Agency, Research Triangle Park, NC. Office of Air Quality Planning and Standards.
Year Published	1980
Call Number	PB80-199045
Report Number	AP-42-ED-3-SUPPL-10;
Abstract	In this Supplement to AP-42, new, revised and updated emissions data are presented for mobile sources; aircraft; transportation and marketing of petroleum liquids; waste solvent reclamation; tank and drum cleaning; hydrofluoric acid; phosphoric acid; sulfur recovery; wine making; harvesting of grain; primary lead smelting; coal cleaning; glass fiber manufacturing; phosphate rock processing; coal conversion; taconite ore processing; plywood veneer and layout operations; woodworking waste collection operations; and explosives detonation. There is also an expansion and revision of the Appendix A, miscellaneous data and conversion factors.

Main Title	Compilation of Air Pollutant Emission Factors, Third Edition (Including Supplements 1-7) Supplement 10.
Corporate Author	Environmental Protection Agency, Research Triangle Park, NC. Office of Air Quality Planning and Standards.
Year Published	1980
Call Number	PB82-232190
Report Number	AP-42-SUPPL-10;
Abstract	In this Supplement to AP-42, new, revised and updated emissions data are presented for mobile sources; aircraft; transportation and marketing of petroleum liquids; waste solvent reclamation; tank and drum cleaning; hydrofluoric acid; phosphoric acid; sulfur recovery; wine making; harvesting of grain; primary lead smelting; coal cleaning; glass fiber manufacturing; phosphate rock processing; coal conversion; taconite ore processing; plywood veneer and layout operations; woodworking waste collection operations; and explosives detonation. There is also an expansion and revision of the Appendix A, miscellaneous data and conversion factors.

Main Title	Williams Air Force Base Air Quality Monitoring Study.
Personal Author	Sheesley, D. C. ; Gordon, S. J. ; Ehlert, M. L. ;
Corporate Author	Northrop Services, Inc., Las Vegas, NV.;Air Force Engineering and Services Center, Tyndall AFB, FL. Engineering and Services Lab.
Year Published	1980
Call Number	AD-A092 165/0
Report Number	EPA-68-03-2591; EPA/600/4-80-037 ; AFESC/ESL-TR-79-33
Abstract	Air quality and meteorological data were collected continuously from a network of five ground monitoring stations located at Williams Air Force Base (WAFB) near Phoenix, Arizona, during June 1976 through June 1977. Data reported here will serve as detailed input for defining the accuracy limits of the Air Quality Assessment Model. The data have been analyzed in order to determine the air quality impact attributable to WAFB operations. Also reported are the preliminary results obtained from several related special studies designed to characterize horizontal and vertical dispersion of WAFB emissions. The data indicate no significant air quality impact at WAFB resulting from aircraft operations. (Author)

Main Title	ENVIRONMENTAL POLLUTION BY CARCINOGENIC HYDROCARBONS DURING AVIATION FUEL COMBUSTION.
Journal Title	GIG SANTI
Personal Author	SMIRNOV GA
Year Published	1981
Call Number	586162

Main Title	Review of Criteria for Vapor-Phase Hydrocarbons.
Personal Author	Tilton, Beverly E. ; Bruce, Robert M. ;
Corporate Author	Environmental Protection Agency, Research Triangle Park, NC. Environmental Criteria and Assessment Office.
Year Published	1981
Call Number	PB82-136516
Report Number	EPA-600/8-81-022;
Abstract	Information on vapor-phase hydrocarbons presented in this document covers basic atmospheric chemistry relative to secondary products, especially ozone; sources and emissions; ambient air concentrations; relationship of precursor hydrocarbons to resultant ozone levels in ambient air; health effects; and welfare effects. The principal conclusions from this document are as follows. Hydrocarbons are a principal contributor to the formation of ozone and other photochemical oxidants; however, no fixed single quantitative relationship between precursor hydrocarbons and resulting ozone concentrations can be defined. This relationship varies from site to site depending on local precursor mixes, transport considerations, and meteorological factors. Consequently no single quantitative relationship can be defined nationwide. While specific hydrocarbon compounds can be of concern to public health and welfare, as a class this group of materials cannot be considered a hazard to human health or welfare at or even well above those concentrations observed in the ambient air.

Main Title: Characteristics of Benzo(a)Pyrene and A-Ring Reduced 7,12-Dimethyl Benz(a)Anthracene Induced Neoplastic Transformation of Human Cells in Vivo.

Personal Author: Tejwani, R. ; Witiak, D. T. ; Inbasekaran, M. N. ; Cazer, F. D. ; Milo, G. E. ;

Corporate Author: Ohio State Univ., Columbus. Dept. of Physiological Chemistry.;Health Effects Research Lab., Research Triangle Park, NC.;Air Force Office of Scientific Research, Bolling AFB, DC.;National Cancer Inst., Bethesda, MD.

Year Published: 1981

Call Number: PB84-174663

Report Number: F49620-80-C-0085, EPA-R-806638; EPA-600/J-81-686;

Abstract: The polynuclear aromatic hydrocarbons (PAH) benzo(a)pyrene (BP) and the A-ring reduced analogue of 7,12-dimethylbenz(a)anthracene (DMBA), 1,2,3,4-tetrahydro-7,12-dimethylbenz(a)anthracene (TH-DMBA) are carcinogenic to human cells. The unsaturated PAH, DMBA exhibits no carcinogenic activity on human cells as measured by growth in soft agar of 84 and 86, respectively. These anchorage independent cells when seeded on the chick embryonic skin (CES) organ cultures, are invasive and form a fibrosarcoma. It is highly unlikely that TH-DMBA, which does not contain an aromatic A-ring, can undergo metabolism in human cells in culture to form a bay region 3,4-dihydrodiol-1,2-epoxide. These results suggest that an alternate mechanism for the induction of carcinogenesis is appropriate to explain the absence of bay region diol-epoxide metabolite as the ultimate form of the carcinogen in TH-DMBA induced carcinogenesis in human diploid cells.

Main Title: Procedures for Emission Inventory Preparation. Volume IV: Mobile Sources.

Corporate Author: Environmental Protection Agency, Research Triangle Park, NC. Office of Air Quality Planning and Standards.

Year Published: 1981

Call Number: PB82-240136

Report Number: EPA-450/4-81-026D;

Abstract: Procedures are described for compiling the complete comprehensive emission inventory of the criteria pollutants and pollutant sources. These procedures described are for use in the air quality management programs of state and local air pollution control agencies. Basic emission inventory elements--planning, data collection, emission estimates, inventory file formatting, reporting and maintenance--are described. Prescribed methods are presented; optional methods are provided. The procedures are presented in five (5) volumes: Emission Inventory Fundamentals, Point Sources, Area Sources, Mobile Sources, and Bibliography.

Main Title	Analytical Methods for the Determination of Polycyclic Aromatic Hydrocarbons on Air Particulate Matter.
Personal Author	Wise, S. A. ; Bowie, S. L. ; Chesler, S. N. ; Cuthrell, W. F. ; May, W. E. ;
Corporate Author	National Bureau of Standards, Washington, DC.; Environmental Protection Agency, Washington, DC.
Year Published	1982
Call Number	PB83-162230
Abstract	Analytical methods for the determination of polycyclic aromatic hydrocarbons (PAH) on urban air particulate matter are described. These methods consist of extraction, isolation of PAH by normal-phase liquid chromatography (LC) followed by analysis by gas chromatography (GC) and reversed-phase LC. Quantitative results obtained by GC and LC for an air particulate material, which will be issued as a Standard Reference Material, are compared.

Main Title	Binding of Polychlorinated Biphenyls Classified as Either Phenobarbitone-, 3-Methylcholanthrene- or Mixed-Type Inducers to Cytosolic Ah Receptor.
Personal Author	Bandiera, A. ; Safe, S. ; Okey, A. B. ;
Corporate Author	Guelph Univ. (Ontario). Guelph-Waterloo Centre.; Environmental Research Lab.-Duluth, MN.
Year Published	1982
Call Number	PB83-240788
Report Number	EPA-R-809764; EPA-600/J-82-369;
Abstract	It has been postulated that reversible, high-affinity binding of 3-methyl-cholanthrene (MC)-type inducers to a receptor protein (the Ah receptor) in hepatic cytosol is essential for induction of aryl hydrocarbon hydroxylase (AHH) enzymic activity. To test this postulate, the binding affinities of 16 highly purified, synthetic chlorinated biphenyl (PCB) congeners, which have been categorized either as phenobarbitone (PB)-, MC- or mixed (PB + MC)-type inducers of cytochrome P-450-dependent monooxygenases have been examined. The affinity of individual biphenyl congeners for the receptor was determined by their competition with 2,3,7,8-(3 sup H) tetrachlorodibenzo-p-dioxin ((3 sup H)TCDD) for specific cytosolic binding sites as measured by sucrose density gradient analysis following dextran-charcoal treatment.

Main Title	Characterization of Air Particulate Material for Polycyclic Aromatic Compounds.
Personal Author	Wise, S. A. ; Allen, C. F. ; Chesler, S. N. ; Hertz, H. S. ; Hilpert, L. R. ;
Corporate Author	National Bureau of Standards, Washington, DC.; Environmental Monitoring Systems Lab., Research Triangle Park, NC.
Year Published	1983
Call Number	PB83-155580
Report Number	NBSIR-82-2595;
Abstract	In studies to evaluate the potential health and ecological effects of atmospheric emissions, bioassays have been employed in conjunction with chemical characterization to correlate mutagenic and/or carcinogenic activity with chemical composition. The complexity of an air particulate extract necessitates the prefractionation of the mixture into suitable subfractures or chemical classes prior to chemical characterization and/or biological testing. The goal of this project was to evaluate such a fractionation scheme for air particulate material with respect to chemical characterization of the various fractions with particular emphasis on the identification of polycyclic aromatic hydrocarbons (PAH). In this study the authors have used three chromatographic approaches to separate, identify, and quantify the complex mixture of PAH extracted from SRM 1649 (Urban Dust/Organics): (1) capillary GC, (2) LC with selective fluorescence detection, and (3) multidimensional chromatographic techniques.

Main Title	Recent Advances in EPA's (Environmental Protection Agency's) Monitori and Methods Development Research.
Personal Author	Jungers, Robert H. ;
Corporate Author	Environmental Monitoring Systems Lab., Research Triangle Park, NC. Data Management and Analysis Div.
Year Published	1983
Call Number	PB83-231209
Report Number	EPA-600/D-83-085;
Abstract	Several areas of advanced research related to sampling, analysis, and human exposure assessment of exhaust emission in ambient air have been developed. These include studies of new methods for volatile organic compounds (VOC's), and the development and application of personal exposure monitors (PEM's) in screening for polynuclear aromatics (PNA's) and carbon monoxide (CO). These new methods for screening PNA's are fast, economical and accurate. The more expensive and time consuming traditional methods of analysis may be judiciously applied to those samples which the screening methods indicate are high in PNA's. Carbon monoxide, an emission product directly related to automotive emissions, is being monitored using personal exposure monitors in urban scale studies to obtain data on population exposures on a real time basis. Such data may ultimately be used in assessing more accurately human exposure to mobile source and other emissions.

Main Title	Cyclopenta-Fused Isomers of Benz(a)Anthracene II: Mutagenic Effects on Mammalian Cells.
Personal Author	Nesnow, W. ; Leavitt, S. ; Easterling, R. ; McNair, P. ; Toney, G. E. ;
Corporate Author	Health Effects Research Lab., Research Triangle Park, NC. ;North Carolina Univ. at Chapel Hill. School of Public Health.
Year Published	1984
Call Number	PB84-168772
Report Number	EPA-600/D-84-071,
Abstract	Cyclopenta-fused polycyclic aromatic hydrocarbons (PAH) are a unique class of PAH found in the environment. Acenaphthylene, acephenanthrylene and cyclopenta (cd) pyrene represent characterized cyclopenta-PAH already identified as air pollutants. The pyrolytic synthesis of PAH from two carbon fragments (3) suggests that many more such cyclopenta-ring fusions are possible and may be characterized from environmental samples. Cyclopenta-PAH are non-alternate PAH in which the fused five membered ring provides a new site for metabolic attack by the cytochrome P-450 mixed-function oxidases. The study of the metabolism, metabolic activation and mutagenesis of these chemicals allows a probe into the mechanism of oxygen transfer and the stereo-and regio-specificity of the cytochrome P-450 mixed-function oxidases as well as an understanding of the competition between sites of metabolic action by these enzymes. This chapter is a preliminary report of metabolism and mutagenesis studies with four cyclopenta-fused isomers of benz(a)anthracene: benz(j)aceanthrylene, BjA; benz(e)aceanthrylene, BeA; benz(l)aceanthrylene, BlA; and benz(k)acephenanthrylene, BkA.

Main Title	Mouse Skin Tumor-Initiating Activity of Benz(e)aceanthrylene and Benz(l)aceanthrylene in Sencar Mice.
Personal Author	Nesnow, S. ; Gold, A. ; Sangaiah, R. ; Triplett, L. L. ; Slaga, T. J. ;
Corporate Author	Health Effects Research Lab., Research Triangle Park, NC. ;North Carolina Univ. at Chapel Hill. Dept. of Environmental Sciences and Engineering. ; Oak Ridge National Lab., TN. Biology Div.
Year Published	1984
Call Number	PB85-193738
Report Number	EPA/600/J-84/259;
Abstract	Benz(e)aceanthrylene and benz(l)aceanthrylene, cyclopenta-fused derivatives of benz(l)anthracene, have been reported to be active bacterial cell and mammalian cell gene mutagens. In this study they were evaluated as skin tumor initiators in both male and female SENCAR mice. Both PAH induced papilloma formation in the range of 50-1000 nmol/mouse. Benz(l)aceanthrylene was the most active, being approximately 4 times as activeas benzo(a)pyrene while benz(e)aceanthrylene had activity approximately equivalent to benzo(a)pyrene. These results are in contrast to those reported for the air pollutant, cyclopenta(cd)pyrene, another cyclopenta-fused PAH, which is a weak mouse skin tumor initiator. The authors postulate that these cyclopenta-PAH are formed by pyrosynthetic routes similar to other environmental cyclopenta-PAH and that they may be of importance as contributors to air pollution carcinogenesis. (Copyright (c) 1984 Elsevier Scientific Publishers Ireland Ltd.)

Main Title	Mutagenicity of Cyclopenta-Fused Isomers of Benz(a)anthracene in Bacterial and Rodent Cells and Identification of the Major Rat Liver Microsomal Metabolites.
Personal Author	Nesnow, S. ; Leavitt, S. ; Easterling, R. ; Watts, R. ; Toney, S. H. ;
Corporate Author	Health Effects Research Lab., Research Triangle Park, NC.
Year Published	1984
Call Number	PB85-193969
Report Number	EPA/600/J-84/260;
Abstract	The microsomal metabolites and mutagenic activity of four cyclopenta-fused benz(a)anthracenes; benz(j)aceanthrylene (B(j)A), benz(e)aceanthrylene (B(e)A), benz(l)aceanthrylene (B(l)A) and benz(k)acephenanthrylene (B(k)A) have been studied. Arocolor-1254 induced rat liver microsomes metabolized B(j)A to: B(j)A-1,2-dihydrodiol, B(j)A-9,10-dihydrodiol, B(j)A-11,12-dihydrodiol and 10-hydroxy-B(j)A; B(e)A to: B(e)A-1,2-dihydrodiol, B(e)A-3,4-dihydrodiol, and B(e)A-5,6-dihydrodial; B(l)A to: B(l)A-1,2-dihydrodiol, B(l)A-4, 5-dihydrodiol and B(l)A-7,8-dihydrodiol; and B(k)A to B(k)A-4,5-dihydrodiol and B(k)A-89-dihydrodiol. With each PAH, metabolism occurred on the cyclopentaring. All four isomers were active as gene mutagens in S. typhimurium and in Chinese hamster V79 cells. In the S. typhimurium mutation studies using Aroclor-1254 induced rat liver S9, B(j)A, B(e)A, and B(l)A required significantly less microsomal protein for maximal mutation response than B(k)A and B(a)P suggesting a one-step activation mechanism, presumably on the cyclopenta-fused ring. B(j)A, B(e)A, and B(l)A were significantly more mutagenic than B(k)A and B(a)P in S. typhimurium.

Main Title	Health Effects Assessment for Polycyclic Aromatic Hydrocarbons (PAHS).
Corporate Author	Environmental Protection Agency, Cincinnati, OH. Environmental Criteria and Assessment Office. ; Syracuse Research Corp., NY.
Year Published	1984
Call Number	PB86-134244
Report Number	EPA/540/1-86/013;
Abstract	The document represents a brief, quantitatively oriented scientific summary of health effects data. It was developed by the Environmental Criteria and Assessment Office to assist the Office of Emergency and Remedial Response in establishing chemical-specific health-related goals of remedial actions. If applicable, chemical-specific subchronic and chronic toxicity interim acceptable intakes are determined for systemic toxicants, or q(sub 1)* values are determined for carcinogens for both oral and inhalation routes. A q(sub 1)* was determined for polycyclic aromatic hydrocarbons based on both oral and inhalation exposure. These estimates are based on benzo(a)pyrene, the most potent constituent in PAH containing mixtures identified to date. The text provides information concerning the limitations of these estimates.

Main Title	Health Assessment Document for 1,1, 1-Trichloroethane (Methyl Chloroform). Final Report.
Personal Author	Carchman, R. ; Davidson, I. W. F. ; Greenberg, M. M. ; Parker, J. C. ; Benignus, V. ;
Corporate Author	Environmental Protection Agency, Research Triangle Park, NC. Environmental Criteria and Assessment Office.
Year Published	1984
Call Number	PB84-183565
Report Number	EPA-600/8-82-003F;
Abstract	Methyl chloroform (MC) is a volatile chlorinated hydrocarbon used extensively as an industrial solvent and in consumer products. It has been detected in the ambient air of a variety of urban and non-urban areas of the United States. In certain instances involving contamination of groundwater, much higher levels have been reported. The weight of available evidence obtained from both human and animal data suggest that long-term exposure to environmental levels of MC poses no serious health concern to the general population. No teratogenic potential has been demonstrated for MC in studies conducted to date in rodent species. Available data are inadequate for reaching firm conclusions about its mutagenic potential in humans. Because of the limited usefulness of the animal bioassays conducted to date, it is not possible to classify MC in regard to its carcinogenic potential in humans.

Main Title	Review of Sampling and Analysis Methodology for Polynuclear Aromatic Compounds in Air from Mobile Sources.
Personal Author	Chuang, C. C. ; Petersen, B. A. ;
Corporate Author	Battelle Columbus Labs., OH.;Environmental Monitoring Systems Lab., Research Triangle Park, NC.
Year Published	1985
Call Number	PB85-227759
Report Number	EPA-68-02-3487; EPA/600/4-85/045;
Abstract	The objective of the program was to review and recommend test compounds and sampling and analysis methods for a future EPA study of polynuclear aromatic hydrocarbons (PAH) in microenvironments. Review of PAH profiles in ambient air indicated that concentrations of PAH were generally higher in winter than summer and varied with climate and between sampling sites within an urban area. Levels of several PAH were found to be proportional to traffic density. Studies of the biological activity of ambient air samples showed that some PAH and their nitrated derivatives are extremely carcinogenic and mutagenic. The following compounds were determined to be the most prevalent and mutagenic in ambient air and were recommended for the future EPA study: phenanthrene, pyrene, cyclopenta(c,d)pyrene, benzo(a)pyrene, dibenz(a, h)anthracene, 1-nitropyrene, fluoranthene, benz(a)anthracene, benzo(e)pyrene, benzo(g,h, i)perylene, coronene, and 3-nitrofluoranthene. In the review of PAH sampling methods, collection of both gaseous and particulate bound PAH was determined to be necessary to accurately characterize health effects of PAH in ambient air. Most studies have used filters to sample particulate-bound PAH and absorbents to collect vapor phase PAH. The major sampling problems encountered in the studies were PAH losses due to volatilization and reactivity.

Main Title	Evaluation and Estimation of Potential Carcinogenic Risks of Polynuclear Aromatic Hydrocarbons (PAH).
Personal Author	Chu, M. M. L. ; Chen, C. W. ;
Corporate Author	Environmental Protection Agency, Washington, DC. Office of Health and Environmental Assessment.
Publisher	Jan 85
Year Published	1985
Call Number	PB89-221329
Report Number	EPA/600/D-89/049 ;OHEA-C-147;
Abstract	The evaluation and estimation of the potential risk of human exposures to a hazardous substance requires the analysis of all relevant data to answer two questions: does the agent cause the effect and what is the relationship between dose (exposure) and incidence of the effect in humans. For polynuclear aromatic hydrocarbons (PAH), carcinogenicity is the effect of concern. Three types of evidence can be used to evaluate the likelihood that a PAH is carcinogenic to humans. They are epidemiologic evidence, experimental evidence derived from long-term animal bioassays, supportive or suggestive evidence from short-term tests, metabolism, pharmacokinetics and structure-activity correlations. Mathematical modeling can be used to estimate the potential human risks. The approaches and the problems associated with these approaches for estimating cancer risk to humans are addressed with special emphasis on problems related to PAH.

Main Title	Metabolic Activation Pathways of Cyclopenta-Fused PAH (Polycyclic Aromatic Hydrocarbons) and Their Relationship to Genetic and Carcinogenic Activity.
Personal Author	Nesnow, S. ; Gold, A. ; Mohapatra, N. ; Sangaiah, R. ; Bryant, B. J. ;
Corporate Author	Health Effects Research Lab., Research Triangle Park, NC.
Year Published	1985
Call Number	PB85-236099
Report Number	EPA/600/D-85/161;
Abstract	Cyclopenta-fused PAH are a novel class of environmental PAH of which the most well known example is cyclopenta(cd)pyrene. The fusion of an unsaturated cyclopenta-ring on a PAH in general, markedly enhances its activity as a gene mutagen in bacteria and cultured mammalian cells, a cell transforming agent in rodent cells and a mouse skin tumor initiator. A series of four cyclopenta-fused isomers of benz(a)anthracene and the cyclopenta-fused isomers of anthracene and phenanthrene were studied with respect to the major rat liver microsomal metabolites, their activity as gene mutagens in Salmonella typhimurium and Chinese hamster V79 cells and their ability to morphologically transform C3H10T1/2CL8 mouse embryo fibroblasts. For all six isomers, the dihydrodiol arising from oxidation and hydration at the cyclopenta-ring was a major pathway in Aroclor-1254 induced rat liver microsomes. All six isomers were active in mutating Salmonella typhimurium and the four benz(a)anthracene isomers active in mutating V79 cells at the HGPRT locus.

Main Title	Health Effects Assessment for Acenaphthene.
Corporate Author	Environmental Protection Agency, Cincinnati, OH. Environmental Criteria and Assessment Office. ; Syracuse Research Corp., NY.
Year Published	1987
Call Number	PB88-182068
Report Number	EPA/600/8-88/010;
Abstract	Because of the lack of data for the carcinogenicity and threshold toxicity of acenaphthene risk assessment values cannot be derived. The ambient water quality criterion of 0.2 mg/l is based on organoleptic data, which has no known relationship to potential human health effects. Acenaphthene has been shown to produce nuclear and cytological changes in microbial and plant species. Results of acenaphthene mutagenicity studies in microorganisms and carcinogenicity study are negative. Despite the negative results in the newt (Triturus cristatus) the fact that acenaphthene is a polynuclear aromatic hydrocarbon (PAH), a class of chemicals that contain carcinogens, the carcinogenic potential of acenaphthene is of great concern. Inadequate evidence to allow any conclusion regarding carcinogenicity for humans appropriately places acenaphthene in EPA Group D.

Main Title	THE EFFECT OF FUEL. . .ON EXHAUST EMISSIONS. SAE TECH PAP SER 710012.
Personal Author	FLEMING RD.
Call Number	100522 Accession Number 122329
Main Title	Pollutant formation in heterogeneous mixtures of fuel drops and air
Personal Author	Rink, Karl Kuno
Year Published	1987
OCLC Number	19751639

Main Title	Assessment of Neurobehavioral Response in Humans to Low-Level Volatile Organic Compound (VOC) Sources.
Personal Author	Otto., D. A. ;
Corporate Author	Health Effects Research Lab., Research Triangle Park, NC. Human Studies Div.
Publisher	Jun 91
Year Published	1991
Call Number	PB91-233353
Report Number	EPA/600/D-91/218;
Abstract	Occupants of sick buildings often complain of CNS symptoms including headache and memory loss, but little objective evidence of neurobehavioral effects exists. Available evidence of neurobehavioral effects of low level VOC exposure representative of new buildings is reviewed. Methods suitable for studying the neurobehavioral effects of low-level VOC exposure--including computerized behavioral tests, balance tests and sensory evoked potentials--are reviewed. The use of computerized behavioral tests in conjunction with symptom questionnaires is recommended for low-level VOC studies.

NATIONAL TECHNICAL INFORMATION SERVICE (NTIS)

TI: Experiments and Modeling of Multi-Component Fuel Behavior in Combustion. Final rept. 30 Sep 83-31 Mar 84 on Phase 1.

AN: ADB0849760XSP

AU: Solomon-P.R.

CS: Performer: Advanced Fuel Research, Inc., East Hartford, CT.

RD: May 84. 65p.

AB: An important Air Force objective is to develop technology to allow the utilization of aviation fuels with a broader range of properties including lower hydrogen content and higher aromaticity. The objectives of this program are to develop a data base and modeling capabilities to relate vaporization, pyrolysis, and soot formation to the properties of the fuel, the atomizer and combustion conditions. The benefits of reduced soot in jet engines are significant: increased life, improved reliability of combustor liners and reduced pollution. In addition, reduction of the IR emission from military jet engines is important for lowering an aircraft's visibility for tracking and targeting.

RN: AFWALTR842063

TI: Outline of a New Emissions Model for Military and Civilian Aircraft Facilities.

AN: DE84016455XSP

AU: Rote-D.M.

CS: Performer: Argonne National Lab., IL.

Funder: Department of Energy, Washington, DC.

RD: Jan 84. 60p.

AB: The proposed computational version of the Airport Vicinity and Air Pollution (AVAP) model and the Air Quality Assessment Model (AQAM) is intended to meet the need for computer models usable by a wider community of users on small, modern minicomputers. This new computational system is discussed in Sec. 9 of Volume III of the Federal Aviation Administration report series entitled Impact of Aircraft Emissions on Air Quality in the Vicinity of Airports. The present report is, in effect, an appendix to that discussion and contains a detailed series of computer program flowcharts. These figures show the overall structure of the system as well as the detailed structure of the most important components of the emissions portion of the system. For the most part, these portions are applicable to both civilian and military facilities. The few exceptions requiring special treatment are indicated. The dispersion portion of the system, which is envisioned as being common to both the civilian and military versions of the system, has not yet been designed. This report also contains detailed descriptions of the structures and contents of the major data files used to store input and output data and to transfer data between the independently executable computer codes that make up the entire system. An example of a possible interactive data-file program designed to simplify the task of compiling and editing the various data files is also presented. 12 figures, 20 tables. (ERA citation 09:041144)
RN: ANLEESTM253

TI: Impact of Aircraft Emissions on Air Quality in the Vicinity of Airports. Volume 3. Air Quality and Emission Modeling Needs. Final rept.

AN: ADA147951SXSP

AU: Rote-D.M.

CS: Performer: Argonne National Lab., IL. Energy and Environmental Systems Div.

Funder: Federal Aviation Administration, Washington, DC. Office of Environment and Energy.
Funder: Air Force Engineering and Services Center, Tyndall AFB, FL. Engineering and Services Lab.

RD: Jan 84. 122p.

AB: The first part of this report addresses the status of the AVAP (Airport Vicinity Air Pollution) model and AQAM (Air Quality Assessment Model) from the perspective of the modeling requirements of users concerned with air-quality problems in civilian and military aviation. Brief descriptions of the types of problems likely to be encountered is followed by a detailed discussion of those characteristics of the problems that determine the technical requirements for the applicable computation procedures or models. This is followed by a discussion of the operational or user requirements of the models. Then a review and evaluation of the AVAP model and AQAM is given that includes a discussion of their intended uses, strengths, and weaknesses. The methods used by the two models to treat various aspects of the emission and dispersion are compared, and the best methods are selected, or alternatives are recommended where appropriate. The latter portion of the report addresses the future needs. Because of the number of interrelated problems and decisions required to meet these needs, a systematic approach to the problem in the form of a 'decision tree' is presented. The final section contains an outline of a proposed new computational system that should alleviate at least some of the problems identified in earlier sections. Two objections were paramount in the new design: to make the model easier to use and to be able to implement the model on modern, small computers.

RN: FAAEE8413, , AFESCESLTR8435

TI: Impact of Aircraft Emissions on Air Quality in the Vicinity of Airports. Volume 4. Nitrogen Dioxide and Hydrocarbons. Final rept. Jul 80-Apr 84.

AN: ADA1482538XSP

AU: Brubaker-K.L.; Dave-M.; Wingender-R.J.; Flotard-R.D.

CS: Performer: Argonne National Lab., IL. Energy and Environmental Systems Div.

Funder: Federal Aviation Administration, Washington, DC. Office of Environment and Energy.

Funder: Air Force Engineering and Services Center, Tyndall AFB, FL. Engineering and Services Lab.

RD: Apr 84. 158p.

AB: This report documents the results of three related studies conducted to assess the impact of aircraft emissions of nitrogen oxides (NOx) and hydrocarbons (Hc) on air quality. The first study consisted of a field program carried out at O'Hare International Airport and an associated model development program, the purposes of which were to assess the effect of aircraft NOx emissions on ambient 1-hour concentrations of nitrogen dioxide (NO2) and to provide a dispersion model suitable for the prediction of such concentrations. The second study involved the collection and laboratory analysis of samples of hydrocarbons in ambient air contaminated by jet aircraft exhaust, together with a determination of the type and relative amounts of the various hydrocarbons detected. The third study consisted of an analysis, based on available data in the literature, of the potential role of aircraft hydrocarbon emissions in the production of photochemical smog. The available literature dealing with the issue of aircraft contributions to photochemical smog has been reviewed and is discussed. At present, the available information is insufficient to evaluate the effect quantitatively. The requirements for further work that would enable a quantitative evaluation to be made are discussed.

RN: FAAEE8414, , AFESCESLTR8436

TI: Aircraft Engine Emissions Estimator. Final rept. Jan 83-Sep 85.

AN: ADA1645522XSP

AU: Seitchek-G.D.

CS: Performer: Air Force Engineering and Services Center, Tyndall AFB, FL. Engineering and Services Lab.

RD: Nov 85. 101p.

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

RN: AFESCESLTR8514

TI: Turbine Engine Exhaust Hydrocarbon Analysis. NTIS Tech Note.

AN: NTN861210XSP

CS: Performer: Department of the Air Force, Washington, DC.

RD: Nov 86. 1p.

AB: This citation summarizes a one-page announcement of technology available for utilization. Methods of sampling and analysis of jet turbine engine emissions were developed and applied to two full-scale engines and a combustor rig. This research provided an accounting of 98 percent of the organic emissions and an evaluation of their contribution to photochemical reactivity. It was found that the contribution of jet aircraft emissions to photochemical air pollution is small, and probably has been over-estimated in the past. It was also shown that combustor rigs may not be used as a surrogate for full-scale engines when studying exhaust emissions. These data are applicable to all DOD, federal, state, and local government and private agencies involved in the evaluation and/or control of air pollution. It also has application in the development of new turbine engines and fuels.

TI: Aircraft Emissions Characterization: TF41-A2, TF30-P103, and TF30-P109 Engines. Final rept. Dec 85-Mar 87.

AN: ADA192053 7XSP

AU: Spicer-C.W.; Holdren-M.W.; Miller-S.E.; Smith-D.L.; Smith-R.N.

CS: Performer: Battelle Columbus Labs., OH.

Funder: Air Force Engineering and Services Center, Tyndall AFB, FL. Engineering and Services Lab.

RD: Dec 87. 76p.

AB: Assessment of the environmental impact of aircraft operations is required by Air Force regulations. This program was undertaken with the aim of quantifying the gaseous and articulate emissions associated with three Air Force turbine engines. These engines were 41-A2, TF30-P103, and TF30-P109. The emissions tests were carried out, using a test cell Tinker AFB, Oklahoma City, OK. All tests employed JP-4 as the fuel, and fuel samples were characterized by standard tests and analyzed for composition. Emissions were measured at power settings of idle, 30 percent, 75 percent, 100 percent, and afterburner (where appropriate). Measurements were made of detailed organic composition, CO, CO2, NO, NOx, smoke number, particle concentration, and particle size distribution. A multiport sampling rake was used to sample the exhaust, and heated Teflon tubing was used to transfer exhaust to the monitoring instrumentation. Measured and calculated fuel/air ratios were compared to assure representative sampling of the exhaust.

RN: AFESCESLTR8727

TI: Aircraft Emissions Characterization. Final rept. Sep 86-Aug 87.

AN: ADA1978642XSP

AU: Spicer-C.W.; Holdren-M.W.; Miller-S.E.; Smith-D.L.; Smith-R.N.

CS: Performer: Battelle Columbus Labs., OH.

Funder: Air Force Engineering and Services Center, Tyndall AFB, FL. Engineering and Services Lab.

RD: Mar 88. 74p.

AB: Assessment of the environmental impact of aircraft operations is required by Air Force regulations. This program was undertaken to quantify gaseous and particulate emissions associated with three Air Force turbine engines (TF33-P3, TF33-P7, and J79 (smokeless). The emissions tests were carried out, using a test cell at Tinker AFB, Oklahoma City, OK. All tests employed JP-4 as the fuel, and fuel samples were characterized by standard tests and analyzed for composition. Emissions were measured at power settings of idle, 30 percent, 75 percent, and 100 percent. Measurements were made of detailed organic composition, CO, CO2, NO, NOx, smoke number, particle concentration, and particle size distribution. A multiport sampling rake was used to sample the exhaust, and heated Teflon tubing was used to transfer exhaust to the monitoring instrumentation. Measured and calculated fuel/air ratios were compared to assure representative sampling of the exhaust. The results have been used to calculate emission indices and emission rates for CO, CO2, total hydrocarbons, NO, NO2, and NOx. The distribution of organic compounds in the exhaust from the different engines and at various power settings has been compared, and the distribution by compound class and by carbon number are reported. Smoke numbers and particle size distributions have been derived from the test data. The report also contains a review of the emissions of selected toxic chemicals, and a comparison with other emission sources. (FR)

RN: AFESCESLTR8763

TI: Aircraft Emissions Characterization: F101 and F110 Engines. Final rept. Jun 87-Mar 89.

AN: ADA2342517XSP

AU: Spicer-C.W.; Holdren-M.W.; Smith-D.L.; Miller-S.E.; Smith-R.N.

CS: Performer: Battelle Columbus Labs., OH.

Funder: Air Force Engineering and Services Center, Tyndall AFB, FL. Engineering and Services Lab.

RD: Mar 90. 79p.

AB: Assessment of the environmental impact of aircraft operations is required by Air Force regulations. This program was undertaken to quantify gaseous and particulate emissions associated with two Air Force turbine engines (F101 and F110). The emissions tests were carried out using a test cell at Tinker AFB, Oklahoma City, OK. All tests employed JP-4 as the fuel, and fuel samples were characterized by standard tests and analyzed for composition. Emissions were measured at five power settings for each engine. Detailed organic composition, CO, CO2, NO, NOx, smoke emissions, particle concentration, and particle size distribution were measured. A multiport sampling rake was used to sample the exhaust, and heated Teflon tubing was used to transfer exhaust to the monitoring instrumentation. Measured and calculated fuel/air ratios were compared to assure representative sampling of the exhaust.

RN: AFESCESLTR8913

TI: ETBE in General Aviation Aircraft Engines. Abstract Only.

AN: N9112565BXSP

AU: Marshall-W.F.

CS: Performer: National Inst. for Petroleum and Energy Research, Bartlesville, OK.

Funder: National Aeronautics and Space Administration, Washington, DC.

RD: May 90. 1p.

AB: Tests were conducted to determine the potential of using ethyl tertiary-butyl ether (ETBE) as a fuel for light aircraft engines. An engine was installed on a test stand and operated at two speed-load conditions with five fuels. The fuels were avgas, an unleaded premium autogas, blends of ETBE in the autogas, and neat ETBE. The air-fuel mixture was controlled at five different stoichiometries at each engine mode. Engine performance and exhaust emissions were measured at each condition. The exhaust emissions measurements included hydrocarbon speciation and aldehydes as well as total hydrocarbon, CO, NOx, O2, and CO2. Results show that the engine performance achieved with ETBE (either blended or neat) was equivalent to that with hydrocarbon fuels. Thermal efficiency was slightly higher for ETBE. However, the lower emission rates of the reactive components with ETBE yields a net effect of lesser effect on air quality.

DEFENSE TECHNICAL INFORMATION CENTER (DTIC)

TITLE: Evaluation of Fire Resistant Fuel in the AGT 1500 Gas Turbine Engine.

DESCRIPTIVE NOTE: Final Report, Feb. 87-Mar. 88
Mar. 88, 75 p.

AUTHORS: Vermes, Geza; Roman, Daniel

CONTRACT NO.: DAAE07-87-R021

DTIC REPORT NO.: AD-B130-032

MONITOR: TACOM TR-1337

ABSTRACT: A Fire Resistant Fuel (FRF), developed by Southwest Research Institute, was tested and its performance compared with Diesel Fuel (DF-2) in an ambient pressure/temperature ignition rig; a pressurized combustor rig using preheated air; and in an AGT 1500 gas turbine engine. Atomization characteristics of the fuel were also investigated with a Phase Doppler Particle Analyzer. Test results show that this FRF can provide the same power performance from this 1500 shaft horsepower (SHP) engine as DF-2. The Specific Fuel Consumption (SFC) using FRF was 15% higher, due to the 15% lower heating value of the FRF, as compared with DF-2, i.e., the FRF did not cause thermodynamic or aerodynamic degradation in the engine. Specific fuel consumption was slightly higher at idle. Emissions of hydrocarbons and CO were the same as with DF-2 at full load, somewhat higher at idle. Engine smoke was less than on DF-2. Combustion system wall temperatures were virtually identical with DF-2. Combustor exit temperature distribution was similar to DF-2. Ignition in the engine at 60 F ambient took approximately 6 seconds on FRF, vs. 4 seconds on DF-2.

TITLE: U.S. Air Force Turbine Engine Emission Survey.
Volume I-Test Summaries.
Volume II-Individual Engine Test Reports.
Volume III-Engine Model Summaries.

DESCRIPTIVE NOTE: Final Report, Jan. 75-Jun. 78.
Aug. 78, VOL. I, 195p; VOL II, 172p;
VOL. III, 96p.

AUTHORS: Souza, Anthony F. and Daley, Peter S.

CONTRACT NO.: F29601-75-C-0046

DTIC REPORT NO.: AD-A061-532 (VOL. I)
AD-A061-665 (VOL. II)
AD-A061-483 (VOL. III)

MONITOR: CEEDO TR-78-34-VOL-1
CEEDO TR-78-34-VOL-2
CEEDO TR-78-34-VOL-3

ABSTRACT: The gaseous exhaust emissions from 14 military gas turbine engines were measured at various power levels from idle to full power including afterburning. SAE smoke number was determined. All measurements were made using the Air Force Mobile Emissions Laboratory which is a self-contained state-of-the-are gas turbine emissions test laboratory. Emission rates of hydrocarbons, carbon monoxide and oxides of nitrogen were calculated. The emission rate of sulfur oxides was estimated from fuel analyses. The body of data was analyzed to show relationships among the data. These studies included the effect of power setting on emission index and smoke number, variation of gas concentrations across the exhaust plume and the degree of uncertainty introduced by abbreviated sampling methods. A summary table of 'Best Estimate' emission factors for all the engines tested is provided.

TITLE: Evaluation of a JP-5 Type Fuel Derived from Oil Shale.

DESCRIPTIVE NOTE: Interim report.

AUTHORS: Solash, J., Nowack, C.J. and Delfosse, R.J.
NAVAL AIR PROPULSION TEST CENTER, TRENTON, NJ
PROPULSION TECHNOLOGY AND PROJECT ENGINEERING
DEPT., REPORT NO. NAPTC-PE-82.

DTIC REPORT NO.: AD-A025-417

ABSTRACT: A kerosene fuel derived from oil shale was evaluated for suitability as a substitute for petroleum derived JP-5. Engine performance and gaseous emissions were evaluated using a T63-A-5A engine. Specification analyses were performed to determine conformance with the MIL-T-5624J specification for JP-5 grade fuel. Engine performance of the oil shale derived fuel was equivalent to that of a typical petroleum derived JP-5. while carbon monoxide (CO) and unburned hydrocarbon (THC) emissions of the oil shale fuel were equivalent to those of petroleum fuels, the nitrogen oxides were higher for the oil shale fuel. A high concentration of fuel bound nitrogen was implicated as the cause for the high nitrogen oxide emissions. The oil shale derived fuel was found not to conform to specifications for contamination, existent gums, thermal stability, freeze point and viscosity at -34.5 C (-30 F). A program of post-refinery upgrading studies was initiated in order to improve these deviant properties. This program included filtration, distillation, clay and acid treatment and urea extraction. It was found that no one single post-refinery treatment could improve all deviant properties.

OTHER LITERATURE SOURCES

Title: Advanced Combustors Under Development to Cut Emissions in Conventional Engines

Authors: Kandebo, Stanley W.

Journal: Aviation Week & Space Technology Vol: 135 Iss: 21

Date: Nov 25, 1991 pp: 51-54

Abstract: Power plant manufacturers Rolls-Royce Pratt & Whitney and General Electric (GE) are aggressively pursuing advanced combustors that will reduce aircraft engine emissions by 30% to 50%. In 1991 GE began development testing of a staged low oxides of nitrogen combustor for the GE90 and for the CFM565B. Engine manufacturers are focusing on oxides of nitrogen in conventional transports as opposed to other emissions for several reasons including the potential seriousness of the effects of these compounds on the environment. Studies indicate that aviation engines contribute only an average of 2% to the total oxides of nitrogen emissions in any single country. However that 2% could have a critical environmental effect. Power plant manufacturers say that a variety of methods can be used to reduce oxides of nitrogen emissions. One way is to decrease gas dwell time in the combustion zone. Graphs.