NAPTC-PE-83

NAVAL AIR PROPULSION TEST CENTER

TRENTON, NEW JERSEY 08628

NAPTC-PE-83 JUNE 1976

DISCUSSION OF AIRCRAFT AIR POLLUTION LEGISLATION AND NAVAL AIRCRAFT OPERATIONS

By: A. F. Klarman
R. J. Skoda

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NAPTC-PE-83
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): Discussion of Aircraft Air Pollution Legislation and Naval Aircraft Operations.
5. TYPE OF REPORT & PERIOD COVERED: Final rept.
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): A. F. Klarman, J. Skeba, Richard
8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Air Propulsion Test Center
Fuels and Fluid Systems Division, PE71
Trenton, New Jersey 08628

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
NAVAIR AIRTASK No.
A536536Ø/052F/3W4543ØØØ

11. CONTROLLING OFFICE NAME AND ADDRESS
Commander
Naval Air Systems Command
Washington, DC 20361

12. REPORT DATE: June 1976
13. NUMBER OF PAGES: 22

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for Public Release: Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

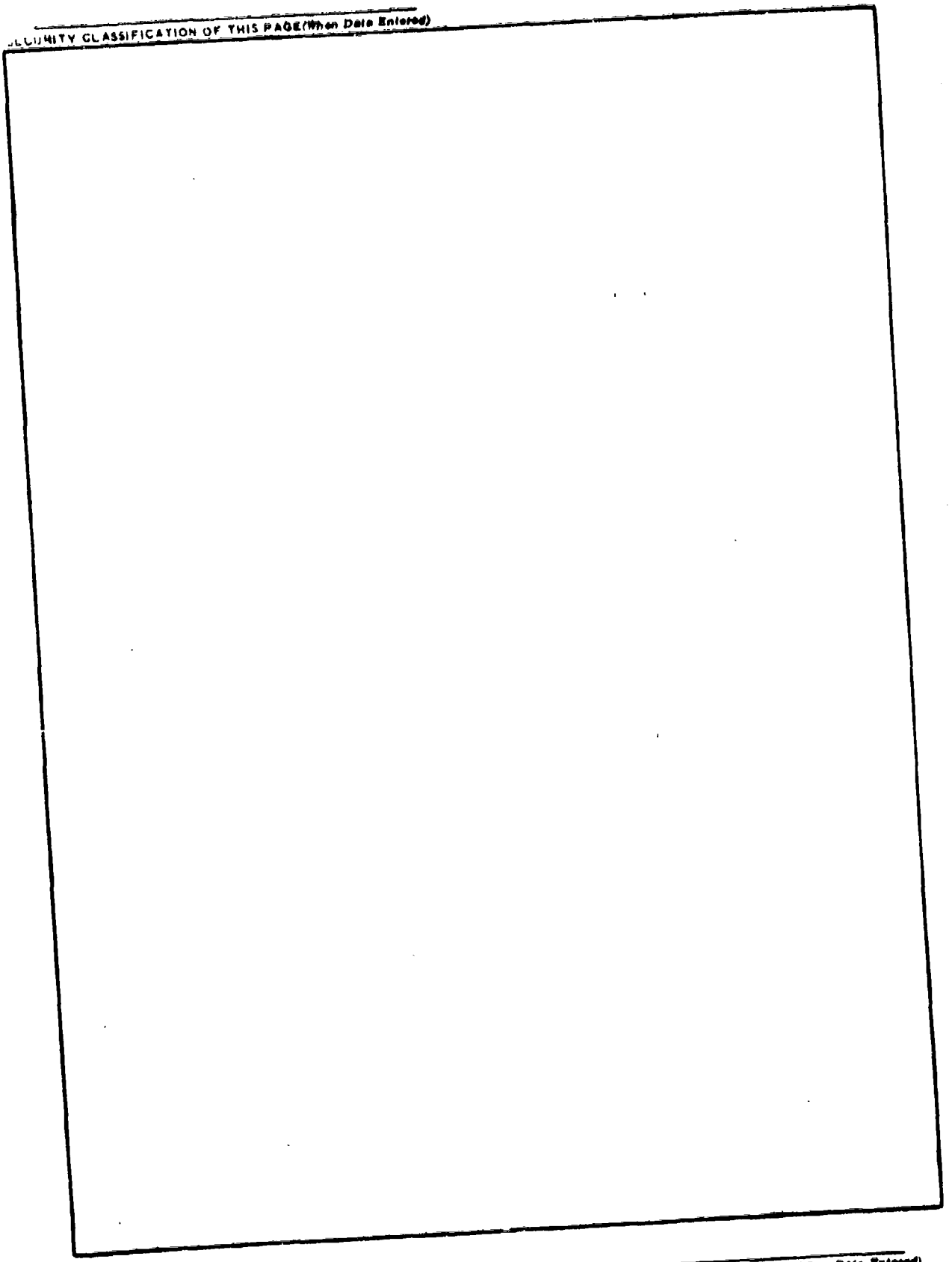
18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Air Pollution Legislation
Aircraft
Gas Turbine Engines

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Information on Laws, Executive Orders and Environmental Protection Agency (EPA) Regulations which could have an effect on naval air operations was surveyed and summarized. Specific analysis of naval air operations was performed in conformance with the EPA Standards for aircraft and aircraft engines and also taking into consideration differences between commercial and naval air operations. The establishment of engine emission goals to be incorporated into new engine development programs was recommended.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED 407 928
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)



NAVAL AIR PROPULSION TEST CENTER

TRENTON, NEW JERSEY 08628

PROPULSION TECHNOLOGY AND PROJECT ENGINEERING DEPARTMENT

NAPTC-PE-83 JUNE 1976

DISCUSSION OF AIRCRAFT AIR POLLUTION LEGISLATION AND NAVAL AIRCRAFT OPERATIONS

Prepared by: A. F. KLARMAN

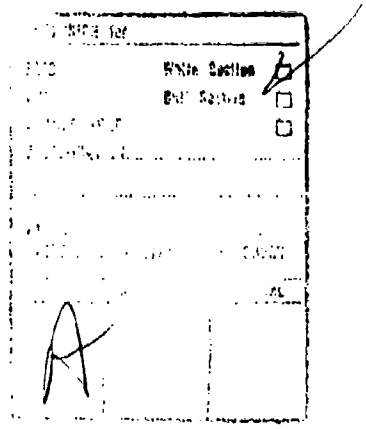
R. J. SKEBA

Approved by: L. MAGGITTI

AUTHORIZATION: NAVAIR AIRTASK No. A5365360-052F-3W45430000
NAVAIR WORK UNIT ASSIGNMENT NAPTC-732-BR6-292

TABLE OF CONTENTS

	Page
REPORT DOCUMENTATION PAGE -- DD Form 1473	
TITLE PAGE	
TABLE OF CONTENTS	i
INTRODUCTION	1
CONCLUSIONS	1
RECOMMENDATIONS	1
DISCUSSION	1 - 11
TABLES 1 AND 2	12 - 13
REFERENCES	14
APPENDIX A	A-1 - A-4
APPENDIX B	B-1
DISTRIBUTION LIST	



INTRODUCTION

The purpose of this report is to review environmental legislation, executive orders, regulations of the Environmental Protection Agency (EPA) and OPNAV Instruction 6240.3D, and to analyze to a limited extent naval air operations. This work was authorized by the Naval Air Systems Command (NAVAIR) Work Unit Assignment NAPTC-732-3R6-292.

CONCLUSIONS

1. Federal activities, by the various acts and excutive orders, have been given the responsibility of monitoring, controlling and abating air pollution from their facilities.

2. Military aircraft are excluded from compliance with the EPA standards for aircraft and aircraft engines.

3. Actual naval aircraft flight cycles at the Miramar Naval Air Station (NAS) differ from those used by the EPA in establishing the Emission Indices of pollutants for aircraft. The difference is not in favor of naval aircraft because it consists primarily of increased idle operation time. Unburned hydrocarbons and carbon monoxide are produced in their greatest concentration in the exhaust gas at the idle operating condition.

4. The validation of the Air Quality Assessment Model (AQAM) for predicting the effect of naval aircraft operations on air quality around an air station is of utmost importance in establishing the degree to which the pollutants from naval aircraft should be decreased.

5. The probability that commercial aircraft engines manufactured after 1979 will meet the EPA Standards to take effect 1 January 1979 appears unlikely at this time.

RECOMMENDATIONS

1. An assessment of the effect of air operations at air stations on local air quality should be made with the AQAM following its validation during 1977.

2. Aircraft engine emission goals as specified in the Discussion Section (paragraph 3.b.(3)) of this report should be applied to all new navy engine development programs.

DISCUSSION

1. This discussion will cover applicable public laws, Federal regulations, and executive orders. These controls have been considered by the Navy in the formulation of OPNAV Instruction 6240.3D which will also be discussed.

It is not the purpose of this report to dwell upon the philosophy of the laws, regulations, and executive orders. This report will acquaint the reader with the purpose and basic content of the applicable controlling documents and provide some analysis of data on naval aircraft and engine operation related to EPA standards. The discussion section is broken down into two parts: (a) review of laws, regulations, executive orders and Navy instructions, and (b) limited analysis of aircraft and engine operation.

2. Review of Laws, Regulations, Executive Orders and Navy Instructions.

a. National Environmental Policy Act (NEPA)

(1) The purpose of this Act (reference 1) are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

(2) This Act is divided into two parts: Title I declares the environmental policy and Title II establishes the Council on Environmental Quality (CEQ). It is in Title I where we find the legislation which can significantly affect the Navy's operations. The Act, in Section 101 of Title I, declares that it is the responsibility of the Federal Government to use all practical means, consistent with other essential considerations of national policy, in carrying out the environmental policy and purpose of the act.

(3) Title II establishes the CEQ in the Executive Office of the President. Some of the functions of the council are:

(a) to assist and advise the President in the preparation of the yearly Environmental Quality Report to Congress which includes a review of the various programs, including deficiencies, of Federal agencies;

(b) to gather timely and authoritative information concerning the conditions and trends in the quality of the environment;

(c) to review and appraise the various programs and activities of the Federal Government in light of the policy set forth in Title I of NEPA;

(d) to document and define changes in the natural environment, and

(e) to establish guidelines for the preparation of Environmental Impact Statements.

b. The Clean Air Act

(1) The Clean Air Act, reference 2, is divided into four titles which: provide for air pollution prevention and control; require emission standards for motor vehicles, fuel, and aircraft; establish administration and regulatory requirements of the Act, and create the Office of Noise Abatement and Control within the EPA and assign its functions.

(2) Title I covers the prevention and control of air pollution. The functions and responsibilities of the EPA are defined, including provisions for an administrator, staff and facilities. The Act requires the establishment of national primary and secondary ambient air quality standards by the EPA Administrator. The State has the primary responsibility for assuring that the air quality within its geographical boundaries does not exceed the primary and secondary ambient quality standards. Each State is required to submit a plan or plans for implementing, maintaining and enforcing the primary and secondary ambient air standards to the EPA Administrator for approval or disapproval. The Act provides the States or a political subdivision, such as a county, with exclusive rights to adopt and enforce air pollution standards and requirements for control and abatement of air pollution, except for provisions contained in the Act governing moving sources. Stationary sources are defined as any building, structure, or installation which emits or may emit any air pollutant.

(3) Title II of the Act is concerned with emissions standards for motor vehicles and aircraft, and the establishment of standards for fuel and fuel additives. The EPA Administrator is responsible for determining which of the emissions are harmful and for setting standards against them. As a result of his finding, an EPA Regulation was issued setting standards for carbon monoxide, oxides of nitrogen, unburned hydrocarbons and smoke from aircraft and aircraft engines. This regulation will be discussed in paragraph h. of this section. The Secretary of Transportation is required to enforce the standards on motor vehicles, aircraft, fuels and fuel additives and, in the aircraft case, to insure that safety of flight considerations are included in the formulation of emission standards.

(4) The two main points of Title III of the Act are the sections covering citizen suits and Federal procurement procedures. Section 304 permits citizen suits, that is, private actions by citizens acting in their own behalf. This section does not authorize the so called "class action" suits. Any person may commence a civil action against any person, including the United States Government, who is in violation of an emission standard, limitation, or order, or against the Administrator if he fails to perform an act or duty required by the Clean Air Act. This Title also prohibits Federal facilities from contracting with anyone convicted of violating a standard. The prohibition is to continue until the administrator certifies that the cause of the violation has been corrected.

(5) Title IV is concerned with noise pollution and requires the Administrator to establish an Office of Noise Abatement and Control, to conduct investigations of noise, and to report his findings to the President and Congress.

c. Executive Order 11514 - Protection and Enhancement of Environmental Quality

(1) This executive order, reference 3, identifies specific executive and administrative responsibilities to implement the environmental policy of NEPA. It provides, in greater detail, the responsibilities of Federal agencies in carrying out the policies of NEPA. Some of the detailed responsibilities are to monitor, evaluate, and control the effects of their respective activities upon the environment and to develop procedures to ensure public understanding of the Federal activities' environmental plans. The CEQ will review and recommend Federal programs to enhance the environment and publish guidelines for preparation of environmental impact statements.

d. Executive Order 11738 - Providing for Administration of the Clean Air Act and the Federal Water Pollution Control Act with Respect to Federal Contracts, Grants and Loans

(1) This executive order, reference 4, prohibits Federal activities from procuring or contracting goods, services and materials from convicted violators under the appropriate section of Clean Air and Water Pollution Control Acts. Exemption can be granted in the paramount interest of the United States Government by the head of a Federal agency after consultation with the EPA administrator. The order directs that the Federal Procurement Regulations, Armed Services Procurement Regulations, and related procurement regulations be amended to provide for compliance with standards issued for carrying out the purposes of the Acts.

e. Executive Order 11752 - Prevention, Control and Abatement of Environmental Pollution At Federal Facilities

(1) The purpose of this order, reference 5, is to require all Federal facilities to conform to applicable local, interstate, State and Federal standards. The term "facility" as used in this order is all-inclusive and means any buildings, installations, structures, land, public works, equipment, aircraft, vessels, and other vehicles and property, owned by or constructed or manufactured for the purpose of leasing to, the Federal Government. The impact that local, interstate and State regulation authorities can have on Federal facilities is limited by the following excerpt: "In light of the principle of Federal supremacy embodied in the Constitution, this order is not intended, nor should it be interpreted, to require Federal facilities to comply with State or local administrative procedures with respect to pollution abatement and control." The preservation of the Federal supremacy doctrine does not relieve Federal agencies of the responsibility to cooperate with these

air pollution agencies in the control and abatement of environmental pollution. Responsibilities of department heads for requesting funds for facility improvements, modification or new facilities with respect to air and water pollution are outlined. The order also establishes a relationship between the EPA administrator and heads of Federal facilities in that he shall: be consulted on applicable standards, mediate conflicts between Federal and various State and local air pollution governing agencies, provide liaison between the governing agencies, and offer technical advice and assistance.

f. EPA Regulations on Prior Notice of Citizen Suits Under The Clean Air Act

(1) The publication of the regulation (reference 6) satisfies the requirement of the Clean Air Act that the EPA prescribe procedures governing notices of civil actions for violations under the Act. A person can take action against the EPA Administrator for failure to perform duties defined in the Act; or against person(s) responsible for a facility which is or has violated a standard or limitation established by the EPA.

g. Council on Environmental Quality - Guidelines on Preparation of Environmental Impact Statements

(1) Guidelines for environmental impact statements (EIS) were issued by CEQ in reference 7. These guidelines are intended to provide a consistent and common format for all Federal agencies. The guidelines require an initial assessment from which a draft environmental impact statement is made and circulated to the public and other pertinent Federal, State, and local agencies for comment. The responses are reviewed by the designated agency writing the EIS and are appropriately formulated, as necessary, in the final EIS. The initial assessment should be made concurrently with the technical and commercial studies. The preparation of the statement requires that the agency has gathered, taken or searched all data and information relevant to the issue. Studies should be directed to show good faith objectivity towards environmental considerations rather than subjective impariality. In all cases, the assessment must be completed before the decision is made to submit the proposal for legislation.

(2) The guidelines require that an EIS contain:

(a) a description of the proposed action, a statement of the purpose of the action and a description of the environment affected;

(b) the relationship of the proposed action to land use plans, policies, and controls for the affected areas;

(c) the probable impact of the proposal on the environment;

(d) alternatives to the proposed action, including those not within the existing authority of the responsible agency;

(e) any possible adverse environmental effects which cannot be avoided;

(f) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity;

(g) any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented; and

(h) an indication of what other interests and considerations of federal policy are thought to offset the adverse environmental effects of the proposed action.

h. EPA Regulations and Control of Air Pollution from Aircraft and Aircraft Engines

(1) The EPA, in reference 8, issued a regulation presenting standards for emissions from aircraft engines and, in reference 9, has proposed standards for emissions from supersonic aircraft engines. These standards prohibit fuel venting or dumping from any aircraft or aircraft engine and limit the quantity of emissions of carbon monoxide, oxides of nitrogen, unburned hydrocarbons and smoke from gas turbine and piston engines dependent on engine work output and type. Table I is a summary of these standards for subsonic and supersonic aircraft engines. These standards apply only to those aircraft with a U.S. or foreign airworthiness certificate. U.S. military aircraft do not possess airworthiness certificates. It must be assumed that the EPA intended to exclude military aircraft from complying with these standards.

(2) The regulation also includes test procedures for sampling and measuring exhaust emissions and procedures for calculating an emission index (EI). The EPA EI is a parameter used in characterizing the emission level of an engine for comparison purposes against the standard. The test procedures and systems specified in the regulations represent the state-of-the-art. It can be expected that, as improvements and advancements are made in the equipment, instruments and techniques, the test procedures and system specifications will change accordingly. The Secretary of Transportation, through the Federal Aviation Administration (FAA), has promulgated Special Federal Aviation Regulation (SFAR) No. 27 (reference 10) requiring compliance to the prohibition of fuel venting or dumping in all commercial aircraft and enactment of engine exhaust emissions standards effective 1 February 1974 for a smoke number of 30 applicable to the JT8D model engine class, only. Other SFAR's relating to future effective dates of other parts of the EPA regulation will be enacted by the FAA as necessary. These emission standards will be discussed further in the section dealing on the "Limited Analysis of Aircraft and Engine Operations."

1. OPNAV 6240.3D Instruction

(1) The OPNAV 6240.3D Instruction, reference 11, implements Navy policy concerning the NEPA, Clean Air Act, and executive orders towards preventing, controlling and abating pollution from its facilities. This instruction provides guidelines and management responsibility, and establishes the Naval Environmental Protection Support Service (NEPSS). The functions assigned to NEPSS are:

(a) Identify and quantify Navy sources of pollution so that appropriate corrective actions can be programmed and funded.

(b) Assure that waste discharges from naval facilities are in compliance with regulations/standards.

(c) Assist commands in preparation of information for EPA permits and state implementation plans and follow-up operating reports as required.

(d) Analyze environmental protection data and trends, evaluate new methods of instrumentation, sampling techniques, and data handling.

(e) Assist commands in data analysis in support of corrective measures, procedures, or projects.

(f) Collect ambient data, as required, to meet specific local/State requirements.

(g) Provide reliable and accessible information to all Navy and Marine Corps commands.

3. Limited Analysis of Aircraft and Engine Operation.

a. The total effect that a NAS can have on local ambient air quality is a summation of the contribution from each facility within its boundaries. For the purpose of this report, facilities shall be limited to aircraft only. Aircraft operations can be affected by regulations governing aircraft as a source of emissions and as a contribution to ambient air quality of a NAS.

b. Aircraft as a Source.

(1) The EPA has promulgated standards which are to be applied to new and in-use aircraft and aircraft engines. Before an analysis of this regulation can be made, an understanding of how engine emissions levels are manipulated to obtain an index value (the EPA EI) for each of the pollutants is necessary. The index was developed to provide a means for normalizing the emissions of one engine model with another or against standards. The index simulates operations around a commercial airport and is a function of engine work output (thrust or shaft horsepower)

and emission levels (pounds per hour) at specific power mode conditions in a simulated landing take-off cycle (LTO), specifying power mode (idle, maximum power, etc), and time (minutes) in mode. The index is reported in terms of emission mass per work output hours. Table II summarizes the power modes and time in modes to be employed in the LTO's for the classes of engines. An explanation of the calculations required, along with an example, is provided in Appendix A. Appendix B summarizes the gaseous and smoke EPA EI's for gas turbine engines tested by NAPTC. No Navy engine tested has met completely the standards established by the EPA. In fact, commercial engine manufacturers will most likely not be to meet the 1979 gaseous emission standards for their production engines. Current research in developing low pollution combustors has shown that it is possible to reduce emissions in combustion rig studies. These research and development programs are now entering into the evaluation phase of the effects of these reduced emission combustors on engine integrity and flight performance. It will be four or five years before this technology will be available to be incorporated into production engines. Smoke, in general, is not a problem for commercial engines since an aggressive retrofit program to incorporate smokeless combustors was started in the late sixties and is practically completed.

(2) The preamble of the EPA regulations states that the standards are definitely not derived from their (EPA) research work, but actually are levels which in the EPA's judgement will be practicable to achieve for turbine and piston engines. The judgement is a result of public hearings and consultations with the National Aeronautics and Space Administration and the Air Force. These standards are equivalent to emission standards being used as design goals in current research and development low pollution combustor technology programs. The EPA intends to monitor these combustor development programs and will determine if it is feasible to apply this technology to retrofit of existing gas turbine engines or if it is necessary to revise and/or extend the implementation of the 1979 standards. There is one definition used in the regulation which states: "Aircraft means any airplane for which a U.S. standard airworthiness certificate or equivalent foreign airworthiness certificate is issued." This definition eliminates the requirement for military aircraft to meet the EPA standards. Once the technology has been demonstrated to meet these standards in commercial aircraft engines, pressure most likely will be placed upon the EPA via the Citizen suits allowed under the Clean Air Act to have the definition changed to include military engines also.

(3) The Air Force, in reference 12, has proposed pollution goals (they are not absolute design requirements) for gas turbine engines and has recommended that they be adopted as Department of Defense policy to be applied in all future engine development programs. Both the Naval Air Propulsion Test Center (NAPTC) and NAVAIR have reviewed these goals. These goals are contingent upon not impeding the development of new engines

and are summarized below:

Pollutants	1979 Goals	1981 Goals
CO (combustion efficiency at idle)	99%	99.5%
HC (combustion efficiency at idle)	99%	99.5%
NO_x (reduction from uncontrolled level)	25%	50%
Smoke	Invisible	Invisible

NAVAIR has recommended to the Chief of Naval Operation that they be accepted as Navy policy (reference 13). By incorporating these goals in engine development programs, the Navy will take a major step towards reducing the pollutants emitted from its aircraft.

c. Aircraft as a Contributor to Ambient Air Quality.

(1) The EPA, in developing the standards for engine emissions, was attempting to regulate the impact of aircraft operations on ambient air quality around airports. The EPA EI does not provide enough information about the effects of aircraft operations on air quality since these emissions can be distributed in as much as 10 cubic miles of air space under control of the airport or air station. In order to assess the overall effect of air operations, either a computer model which predicts local air quality based on simulated flight operations and emission levels, or actual ambient air monitoring programs are required. To perform a monitoring program at every naval air installation would be very costly and time consuming. The Naval Postgraduate School (NPS) has developed for NAPTC an Air Quality Assessment Model (AQAM) which simulates Navy flight operations (reference 14). This model takes into account stationary and area sources in addition to all types of maneuvers performed by aircraft on and around air stations. A validation of this model is planned for the summer of 1977. Once validated, this model will be capable of assessing the effect of aircraft operation at any other air installation. Also, the model can be used to determine the effect of varying aircraft take-off and landing procedures on local air pollution. It can further be used to determine the limits for aircraft derived pollutants in order to minimize the effect on local air pollution. These limits can be translated to engine limits which would be used for the development of combustion systems for existing and future engines.

(2) In a preliminary study at NAS Miramar on LTO's for military and fighter aircraft, NPS determined the operating times for F-4J and A-4E aircraft, which are compared to the corresponding EPA operating times in the following table.

Aircraft	Operating Mode	Time in Mode, (minutes) Miramar Study	EPA Standard Cycle
F-4J*	Taxi (Out)	24.5	19.0
	Take Off	0.3	1.2
	Climb Out	0.7	2.0
	Descent	-	2.3
	Approach	4.1	1.2
	Taxi (In)	16.6	7.0
A-4E**	Taxi (Out)	25.0	19.0
	Take Off	0.2	0.5
	Climb Out	0.9	2.5
	Descent	-	-
	Approach	4.4	4.5
	Taxi (In)	14.2	7.0

* Utilizes two J79-GE-10 afterburning engines; EPA Class T5.

** Utilizes one J52-P-408 non-afterburning engine; EPA Class T1.

(3) The EI's calculated for these aircraft, based on the LTO's and engine emission values, are shown in the following table.

Aircraft	Pollutant	EI, (lbs/1000 lb-thrust-hr/cycle) Miramar Study	EPA Standard Cycle	EPA Proposed Standard (1979)
F-4J	CO	238.0	72.4	20.6 - 24.7
	HC	53.8	15.8	3.0 - 4.7
	NO_x	12.8	8.9	6.9 - 9.0
A-4E	CO	59.0	30.6	9.4
	HC	35.6	17.8	1.6
	NO_x	5.7	6.4	3.7

The afterburning engine emission data used in computing the F-4J indices were obtained from reference 15.

(4) The LTO cycle employed can have a large effect on the value of pollutant index calculated. It is apparent when comparing the NAS Miramar and EPA LTO cycles that the time spent at idle operation is significantly less in the EPA cycle. This factor contributes greatly to the higher CO and HC EI's at NAS Miramar because engines produce maximum CO and HC at idle.

(5) The effect of aircraft emissions is only part of the total effect that the emissions from an NAS can have on local ambient air quality. Executive Orders 11514 and 11752 define the responsibility of federal activities in monitoring their effects on the environment and in the maintenance of local air quality consistent with the regulations enforced. To date, most local authorities have directed their efforts at reducing and/or eliminating stationary source emissions as a means of controlling ambient air quality.

TABLE I
EPA ENGINE EMISSION STANDARDS*

Engine Class	Air Pollutants	New and in-use engines			Newly certified engines manufactured on or after		
		JAN 1,1974	JAN 1, 1976	JAN 1, 1978	JAN 1, 1979	DEC.31, 1979	JAN 1,1981
T1	HC lbs /1000 lb - thrust-hr /cycle				1 6		
	CO				9 4		
	NO_x				3.7		
	SMOKE				Figure 1		
T2	HC				0 8		0 4
	CO				4 3		3
	NO_x				3		3
	SMOKE		Figure 1 **		Figure 1		Figure 1
T3	HC				0 8		0 4
	CO				4 3		3
	NO_x				3		3
	SMOKE			SN of 25	Figure1		Figure 1
T4	HC				0 8		0 4
	CO				4 3		3
	NO_x				3		3
	SMOKE	SN of 30			Figure 1		Figure 1
T5	HC				3 0 - 4 7		0 8
	CO				20 6 - 24 7		4 3
	NO_x				6 9 - 9 0		3
	SMOKE				Figure 1		Figure 1
P1	HC lb/rated power/cycle					0 0019	
	CO					0 042	
	NO_x					0 0015	
P2	HC lb /1000 hp-hr-cycle				4 9		
	CO				26 8		
	NO_x				12 9		
	SMOKE				Figure 2		
APU	HC lb/1000 hp-hr of power output				0 4		
	CO				5		
	NO_x				3		

No fuel venting emissions shall be discharged from T2 T3 T4 or T5 engines after January, 1974 T1 or P2 after January 1, 1975

Definitions:

New engines-engines which have never been in service

In use engines-engines which are in service

Newly certified engines-engines which are type certified on or after the effective date of the applicable emission standard

T1 Turbofan or turbojet engines except T5 engines with less than 8 000 pounds thrust

T2 Turbofan or turbojet engines except T3 T4 and T5 with 8 000 pounds thrust or greater

T3 Gas turbine engines of the JT3D model family

T4 Gas turbine engines of the JT8D model family

T5 Gas turbine engines employed for propulsion of aircraft designed for supersonic speeds

P1 Aircraft piston engines except radial engines

P2 Aircraft turboprop engines

APU Any engine installed in or on an aircraft exclusive of the propulsion engines

Fuel venting emissions All raw fuel exclusive of hydrocarbons in the exhaust emissions discharged from gas turbine engines

Rated power - Maximum power thrust available for take off at standard day conditions

**T2 with 29 000 pounds thrust or greater

FIGURE 1

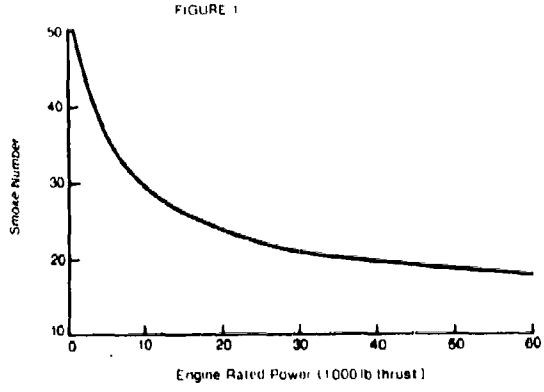
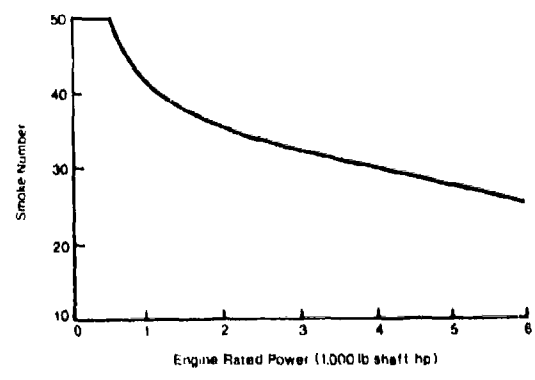


FIGURE 2



*DECEMBER 1973

Prepared by Naval Air Propulsion Test Center

TABLE II

ENGINE OPERATING MODES AND TIME IN MODE

Operating Modes

Mode	Engine Class		
	T1, P2	T2, T3, T4	T5
Taxi/Idle Out	(1)	(1)	(1)
Take-off (2)	100	100	100
Climbout (2)	90	85	65
Descent (2)	N/A	N/A	15
Approach (2)	30	30	34
Taxi/Idle In	(1)	(1)	(1)

(1) The taxi/idle operating modes shall be carried out at a power setting in accordance with applicable Federal Aviation Administration regulations, and the manufacturer's recommended power setting for idle.

(2) Percent of maximum available power.

Time in Mode

Mode	Engine Class		
	T1, P2	T2, T3, T4	T5
Taxi/Idle Out, (min.)	19.0	19.0	19.0
Take-off, (min.)	0.5	0.7	1.2
Climbout, (min.)	2.5	2.2	2.0
Descent, (min.)	N/A	N/A	2.3
Approach, (min.)	4.5	4.0	1.2
Taxi/Idle In, (min.)	7.0	7.0	7.0

REFERENCES

1. PUBLIC LAW: The National Environmental Policy Act, Public Law 91-190, 1970, and as amended.

2. PUBLIC LAW: Clean Air Act, Public Law 91-604, 1970 and as amended.

3. EXECUTIVE ORDER: Executive Order 11514 - Protection and Enhancement of Environmental Quality, March 5, 1970.

4. EXECUTIVE ORDER: Executive Order 11738 - Providing for Administration of the Clean Air Act and Federal Water Pollution Control Act with Respect to Federal Contracts, Grants, or Loans, September 10, 1973.

5. EXECUTIVE ORDER: Executive Order 11752 - Prevention, Control, and Abatement of Environmental Pollution at Federal Facilities, December 17, 1973.

6. REGULATION: EPA Regulation on Prior Notice of Citizen Suits under Clean Air Act, 40CFR54, December 9, 1971.

7. REGULATION: Council on Environmental Quality Guidelines on Preparation of Environmental Impact Statements, 40CFR1500, August 1, 1973.

8. REGULATION: EPA Regulations on Control of Air Pollution from Aircraft and Aircraft Engines, 40CFR87, December 21, 1973.

9. REGULATION: Proposed EPA Regulations on Control of Air Pollution from Supersonic Aircraft, 40CFR87, July 22, 1974.

10. REGULATION: Special Federal Aviation Regulation No. 27 - Fuel Venting and Exhaust Emission Requirements for Turbine Engine Powered Airplanes, 14CFR1, December 26, 1973.

11. INSTRUCTION: OPNAVINST 6240.3D of 24 April 1975.

12. REPORT: Blazowski, W. S. and Henderson, R. E., Aircraft Exhaust Pollution and Its Effect on the U.S. Air Force AFAPL-TR-74-64, August, 1974.

13. LETTER: NAVAIR Letter 53603B:GWG Ser 21 of 8 September 1975.

14. REPORT: Weal, K. I. and Netzer, D. W., Modification of An Ambient Air Quality Model for Assessment of U.S. Naval Aviation Emittants, NPS-57Nt-75071A, August, 1975.

15. REPORT: Lyons, T. F., et al, General Electric Co., Cincinnati, Ohio, Development of Emission Measurement Techniques for Afterburning Turbine Engines, AFAPL-TF-75-52, October, 1975.

APPENDIX A

CALCULATION OF THE EPA EMISSION INDEX

1. The EPA emission index (EI) created confusion in the aircraft industry and governmental agencies because its definition differs substantially from that which has been in use by industry and other government agencies for several years. The "conventional EI" is defined as pounds of constituent per one thousand pounds of fuel (or grams per kilogram) for a specific engine power setting. The values of conventional EI's vary with engine power setting.

2. The EPA EI requires a more complicated calculation than the "conventional EI" and is not related to the conventional EI. It is based on the summation of the constituent for given work output per unit time. The work output is derived from representative landing to take-off cycle (LTO). This index is generally referred to as the "EPA Emission Index" or "EPA Parameter".

3. The calculation of the EPA index for various engine exhaust constituents is fully described in reference 6. To simplify this discussion, the calculations in this appendix will be limited to gas turbine engines; the calculations for the piston engines follow a similar format. The calculation is represented by the general equation below:

$$EI_x \text{ (LB/1000 WORK OUTPUT-HOUR)} = \frac{\sum \frac{\text{CONSTITUENT MASS (LB/HR)}}{\text{ENGINE MODE}} \times \text{TIME IN MODE (HR)}}{\sum \text{WORK OUTPUT} \times \text{TIME IN MODE (HR)}}$$

4. The classes of engines covered by the regulations are listed by their power output, and in certain cases, an actual engine type is named. The classes are listed below:

CLASS	POWER OR SPECIFIC TYPE
T1	8000 lbs thrust or less except T5
T2	8000 lbs thrust or greater except T3, T4, T5
T3	JT3D Family
T4	JT8D Family
T5	Supersonic Transport
P1	All pistons except radials
P2	All turbo-props
APU	Auxiliary power units

From the knowledge as to which class the engine belongs, the power ratings and the time at each power rating are determined, i.e., the LTO to be used in the calculations. At these power settings, corrected for the ambient operating environment of the engine, the respective emission rates of the desired constituents are determined.

LTO MODE	CLASSES T1, P2		CLASSES T2, T3, AND T4	
	Power Setting % Rated	Time In Mode (Min)	Power Setting % Rated	Time In Mode (Mins)
Taxi-Idle Out	*	19	*	19
Take-Off	100	0.5	100	0.7
Climbout	90	2.5	85	2.2
Approach	30	4.5	30	4.0
Taxi-Idle In	*	7.0	*	7.0

* Idle power settings listed here are to be taken as those settings recommended by the engine manufacturer in accordance with the Federal Aviation Administration Regulation.

5. In this example, a J85-GE-2 turbojet, an out of production engine, is used in this appendix as the example for the calculation of the EPA emission index. The engine, rated at 2850 pounds thrust at sea level static, is in the EPA designated "T1 Class" for turbojet engines rated at less than 8000 pounds thrust. The constituent chosen for this example is the hydrocarbon emission. The formula for the hydrocarbon emission rate is:

$$\text{HC emission rate (lb/hr)} = \frac{\left(\frac{HC}{10^4}\right) \times F}{\left(\frac{(CO)}{10^4} + CO_2 + \left(\frac{(HC)}{10^4}\right)\right)}$$

where: F = fuel flow, (lb/hr)

HC = concentration of hydrocarbon in exhaust sample, (parts per million)

CO = concentration of carbon monoxide in exhaust sample, (parts per million)

CO_2 = concentration of carbon dioxide in exhaust sample, (volume percent)

The following data were obtained for the take-off power condition:

HC = 17 ppm

CO = 410 ppm

CO_2 = 3.76%

F = 2890 lb/hr

Substituting these values into the formula yields:

$$\text{HC, lb/hr} = \frac{\frac{17}{10^4} \times 2890}{\left(\frac{410}{10^4} + 3.76 + \frac{17}{10^4}\right)}$$

$$= 1.29 \text{ lb/hr}$$

This calculation is repeated on the data obtained for the approach, climbout and taxi (in and out) modes.

For this example, a matrix, shown below, has been arranged of the engine power, emission rate and times in mode, for simplification in making the final calculations.

CONSTITUENT: HC (HYDROCARBONS)

	1	2	3	4 = 2X3	5 = 1X3
Mode	Thrust (10^{+3}, lb)	Emission Rate (lb/hr)	Time In Mode (hr)	Constituent Mass Mode (lb/hr)	Work Output/Mode lb/hr (10+3)
Taxi-Idle Out	0.200	6.64	0.317	2.103	0.063
Take-Off (100%)	2.905	1.29	0.008	0.010	0.024
Climbout (90%)	2.694	1.28	0.042	0.053	0.112
Approach (30%)	0.838	2.51	0.075	0.188	0.062
Taxi-Idle In	0.200	6.64	0.117	0.775	0.023
			TOTALS	3.130	0.284

The constituent mass and work-output for the LTO are obtained by summing columns 4 and 5 respectively. The EPA EI is calculated by substituting the two sums into the equation:

$$\text{EPA EI, Hydrocarbons} = \frac{\sum \text{(MASS/MODE) time in mode}}{\sum \text{(WORK OUTPUT) time in mode}} =$$

$$\frac{3.130}{0.284} = 11.0 \frac{\text{lb}}{1000 \text{ lb thrust-hour/cycle}}$$

The same procedures are used to compute the EPA EI for carbon monoxide (CO) and oxides of nitrogen (NO_x) shown below:

Constituent	NAPTC Calculated Emission Index	EPA Standard
Hydrocarbons	11.0	1.6
Carbon Monoxide	124.4	9.4
Oxides of Nitrogen	7.1	3.7

APPENDIX B

This appendix contains the EPA emission indices (EI) as determined from measurements conducted by NAPTC on engines at the Center and Naval Air Rework Facility, Norfolk, Virginia. The engine classification and EPA calculation procedures employed are those in reference 6 of the report. Those engines marked with an (H) are helicopter engines. The EPA EI was calculated based on use of that engine in a fixed wing aircraft. This was done only to provide an overview of the current state-of-the-art in engine technology as related to pollution levels. Those indices marked with an asterisk pass the standards set by the EPA for engines manufactured on or after 1 January 1979. These standards are shown in Table I of the report.

ENGINE	EQUIVALENT EPA CLASS	HYDROCARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN	SMOKE
T53-L-13A (H)	P2	15.4	41.7	5.8*	22.8
T55-L-11A (H)	P2	5.1	38.4	6.8	57.0
T56-A-7	P2	18.8	37.0	8.0	67.2
T58-GE-10 (H)	P2	18.1	26.7*	6.7	50.0
T58-GE-16 (H)	P2	15.4	55.4	4.6	-
T63-A-5A (H)	P2	13.1	55.8	3.7	45.0
T64-GE-413 (H)	P2	3.7*	113.4	6.9	63.0
T76-G-10	P2	8.6	44.3	4.3	-
T400-CP-400 (H)	P2	7.6	25.8*	7.9	22.0*
TF34-GE-2	T2	7.4	22.3	3.3	7.9*
TF30-P-6C	T2	5.4	23.8	5.6	-
TF30-P-408	T2	49.3	32.2	6.8	33.2
TF30-P-412A (1)	T2	9.5	25.2	6.9	47.0
J52-P-408	T2	17.8	30.6	6.4	54.7
J79-GE-10 (1)	T2	20.1	90.2	10.0	35.9
J85-GE-2 (1)	T1	11.0	124.4	7.1	21.3*

(1) These are afterburning engines which would normally be in EPA Class T5. They were not operated in afterburning mode during emission measurement program.

DISTRIBUTION LIST

	COPIES
Naval Air Systems Command (AIR-954), Department of the Navy, Washington, DC 02361	8

Intra-Command Addressees

AIR-01B	(1)	AIR-4147A	(1)
AIR-3'0D	(1)	AIR-536B1	(1)
AIR-340E	(1)	AIR-53431B	(1)

Defense Documentation Center for Scientific & Technical Information (DDC), Bldg. No. 5, Cameron Station, Alexandria, Va. 20390	12
Chief of Naval Operations, Navy Department, Washington, DC 20360 (Codes OP451, OP453)	2
Commander, Naval Facilities Engineering Command, 200 Stovall Street, Alexandria, Va. 22332 (Codes: 104, 032B)	2
Commanding Officer, Naval Construction Battalion Center, Port Hueneme, California 93043 (Codes: 25, 251, 252)	3
Superintendent, Naval Postgraduate School, Monterey, California 93940 (Code: 57NT)	1
Commanding Officer, Naval Air Rework Facility, Naval Air Station North Island, San Diego, California 92135 (Codes: 64270)	2
Commanding Officer, Western Division, Naval Facilities Engineering Command, San Bruno, California 94066 (Code-09BE)	1
Commander, Naval Air Forces, Pacific, Naval Air Station North Island, San Diego, California 92135 (Code-722)	1
U.S. Naval Academy, Annapolis, Maryland 21402 (Attn: Prof. J. Williams)	1
U.S. Air Force, Washington, DC 20330 (Codes: PREV 5E425, PREV 5D438)	2
Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio 45433 (Code: SFF)	2
Air Force Civil Engineering Center, Tyndall Air Force Base, Florida 32401 (Code: EV)	2
Army Aviation Systems Command, P.O. Box 209, St. Louis, Missouri 63166 (Code: EFP	1
Chief of Naval Material, Navy Department, Washington, DC 20360 (Codes: 03421, 044P1)	2

	COPIES
Eustis Directorate, USA AMR&DL, Ft. Eustis, Virginia 23402 (Code: SAVDL-EU-TAP)	1
U.S. Marine Corps, Washington, DC 20380 (Code: AAJ)	1
Environmental Protection Agency, Procedures Development Branch, 2565 Plymouth Road, Ann Arbor, Michigan 48105 (Attn: G. Austin)	1
Environmental Protection Agency, 401 M. Street, S.W., Washington, DC 20024 (Attn: G. Kittredge)	1
Department of Transportation, Transportation Systems Center, Cambridge, Massachusetts 02142 (Attn: A. Broderick, Code: TI)	1
Federal Aviation Administration, 2100 2nd Street, Washington, DC 20591 (Attn: W. Westfield, Code: ARD550)	1