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NON-ROAD EMISSION FACTORS OF AIR TOXICS

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INTERIM REPORT NO. 2

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
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Department of Emissions Research
Automotive Products and Emissions
Research Division

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I. INTRODUCTION

There are a number of areas in the United States that do not meet the national ambient air quality standards, despite increasingly stringent highway motor vehicle exhaust regulations. To help meet these ambient standards, other mobile sources of pollution are being examined. There are a number of sources of air pollution that can be classed as mobile, but that are not currently subject to regulations. Some of these sources, such as locomotives, are transportation related; others, such as construction equipment and lawn and garden equipment, are not. The pollution from all these sources is related to their combustion engine.

The Clean Air Act Amendments of 1990 directed the EPA to "...conduct a study of emissions from non-road engines and non-road vehicles (other than locomotives or engines use in locomotives) to determine if such emissions cause, or significantly contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare."[I-1] As part of the work to fulfill the requirements of the Clean Air Act, this report is the second of two reports under this project on emission factors from non-road sources.

A. Objective

There are two objectives of this project. The first objective was to examine the non-road source categories (exclusive of aircraft and locomotives) currently listed in the EPA document commonly referred to as "AP-42",[I-2] and the categories being used by California in their current work in regulating non-road mobile sources, to determine if the individual sources are properly categorized.

The second objective was to obtain the "best currently available" emission factors for each of these categories. For the gaseous emissions of HC, CO, and NOx, this work was to be completed and reported to EPA within 30 days from the start of work. For particulates and toxics the emission factors were to be compiled and reported with 90 days after the start of work.

B. Approach

The work was to be divided into two phases with a report the end of each phase. The first phase was to develop the categories of non-road mobile sources and determine the "best currently available" emission factors for HC, CO, and NO_x. The second phase was to develop a list of toxic emissions from non-road mobile sources and determine the emission factors from non-road mobile sources for these toxic emissions and for particulate matter.

Because of the limited time allotted for this work, a thorough review of the literature and other data sources was not possible. Therefore, the project utilized the reports that were on hand (which were many of the most useful non-road emission reports) and contacts with those persons in EPA and CARB that are working on non-road emission factors to obtain their latest information. For the toxic emissions, computerized searches were made of SAE, ASME, and NTIS literature.

C. Reports

This report is the second of two reports required for this study. The first report presented an analysis of the non-road categories currently used, and recommended a new set of categories. The first report also presented the "best currently available" HC, CO, and NOx emission factors for these categories. This report presents a list of compounds that are emitted from non-road mobile sources that are considered toxic. Where there were measured emissions of these compounds, the report presents emission factors for these toxic compounds for the non-road categories. Where no measured non-road values could be found, emission rates from measurements of other sources are presented. Often these rates are from one or a small group of engines with operating cycles very different from those encountered in non-road equipment. These rates should be used with great care. This report also presents particulate emission factors for the non-road mobile source categories.

REFERENCES FOR SECTION I

I-1 Clean Air Act Amendments of 1990.

I-2 "Compilation of Air Pollutant Emission Factors," Volume II, EPA Report No. AP-42, Fourth Edition, September 1985, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

II. SELECTION OF TOXIC POLLUTANTS FOR EMISSION FACTOR INVESTIGATION

In the broadest sense, all air pollutant emissions of concern to EPA are ultimately toxic, using the dictionary definition of toxic as a synonym of "poisonous." Within the EPA, to groups concerned with mobile source pollutants, the term "toxic" has, in general, come to mean air pollutants that do not have NAAQS levels, but are of concern because of health risks associated with long-term, low-level, exposure. These pollutants include carcinogens, mutagens, and reproductive toxins. Title III of the 1990 Clean Air Act Amendments lists 189 pollutants as "air toxics". These amendments also directed EPA to conduct a study of on-road vehicle air toxics. That study is being conducted by the EPA at their Mobile Source Laboratory at Ann Arbor. The main pollutants being examined are listed in Table II-1. A secondary list of air toxics which mobile sources may emit that are mentioned in Title III is shown in Table II-2.(II-1)

For mobile sources, all pollutants that fall into the category "air toxics" are emitted at much lower levels than the regulated emissions of HC, CO and NO_x. In an extreme situation, such as a large group of vehicles running in a poorly ventilated parking garage, it might be possible for some of the toxic emissions to reach concentrations which could cause short term health effects such as eye irritation or nausea. Before these levels would be reached however, CO would already be at such high concentrations that major adverse health effects would be occurring from the CO levels.

Thus, past studies have examined unregulated pollutants which may exhibit adverse health effects from long term exposure. Mobile source studies have concentrated on carcinogens. The results of a group of studies were reported by EPA in 1989.(II-2) That report examined several air toxics and evaluated their potential as carcinogens. Table II-3, adapted from Reference II-1, lists the cancer-causing potential of several air pollutants. This table and Table II-1 can be used to identify which air toxic emission factors are the most important to obtain for non-road mobile sources.

Based on Table II-3, the five gaseous and two particulate emissions listed in Table II-1 should definitely be included in non-road toxic emission factors. Of the metals listed in Table II-1 only iron (as engine wear products or rust from exhaust systems) might be emitted in sufficient magnitude from non-road engines to warrant inclusion in this study. Engine emissions of copper are much lower than iron, therefore copper was not included in this study. Selenium, platinum, and cerium are associated with catalytic converters, which are not currently installed on non-road sources, with the exception of some diesel mining equipment. Therefore selenium, platinum, and cerium were not included in this study.

The list in Table II-2 includes some compounds that are known to be highly toxic; however, based on studies from highway vehicles, the non-road emissions of these compounds will be exceedingly small, and are not recommended for inclusion in this study. There are several species of hydrocarbons listed in Table II-2, that, taken together, constitute a fair percentage of the total engine exhaust hydrocarbons. However, the long term health effects of these compounds are still under investigation, and these hydrocarbon species were not included in this study.

TABLE II-1. ON-ROAD MOBILE SOURCE AIR TOXICS TO BE EXAMINED BY EPA

Benzene
Formaldehyde
Acetaldehyde
1,3-Butadiene
Diesel Particulate
Gasoline Particulate
Gasoline Vapors

Metals:
- Iron
- Copper
- Selenium
- Platinum
- Cerium

TABLE II-2. OTHER MOTOR VEHICLE TOXICS MENTIONED IN TITLE III OF THE 1990 CAAAs.

Acetonitrile
Acrolein
Acrylic acid
Carbon disulfide
Carbonyl sulfide
Catechol
Chlorine
Cresols/Cresylic acid (isomers and mixture)
Dibenzofurans
Diethyl sulfate
Dimethyl sulfate
1,4-Dioxane (1,4-Diethyleneoxide)
Ethyl benzene
Ethylene dibromide
Ethylene dichloride
Hexane
Lead compounds
Manganese compounds
Methanol
Methyl ethyl ketone
Methyl tert. butyl ether
Naphthalene
Phenol
Polycyclic organic matter
Propionaldehyde
Styrene
Toluene
2,2,4-Trimethylpentane
Xylenes

TABLE II-3. SUMMARY OF RISK ESTIMATES[a]

Motor Vehicle Pollutant	U. S. Cancer Incidences/Year[b]		
	1986	1995	2005
1,3-Butadiene	236 - 269	139 - 172	144 - 171
Diesel Particulate	178 - 860	106 - 662	104 - 518
Benzene	100 - 155	60 - 107	67 - 114
Formaldehyde	46 - 86	24 - 43	27 - 48
Gasoline Vapors	17 - 68	24 - 95	30 - 119
Asbestos	5 - 33	ND[c]	ND
Acetaldehyde	2	1	1
Gasoline Particulate	1 - 176	1 - 156	1 - 146
Ethylene Dibromide	1	<1	<1
Cadmium	<1	<1	<1
Dioxins	ND	ND	ND
Vehicle Interior Emissions	ND	ND	ND

[a]The risk estimates are 95% upper confidence limits
[b]The risk estimates for asbestos, cadmium and ethylene dibromide are for urban exposure only. Risks for the other pollutants include both urban and rural exposure.
[c]ND = Not Determined.

Note: The risk estimates are upper bound estimates; therefore, they are not intended to represent actual numbers of cancer cases but rather can be used to rank the mobile source pollutants and to guide further study.

TABLE II-4 AIR TOXICS RECOMMENDED FOR INCLUSION IN NON-ROAD EMISSION FACTOR STUDY

Benzene
Formaldehyde
Acetaldehyde
1,3-Butadiene
Gasoline Vapors
Diesel Particulate
Gasoline Particulate
Iron

Lead has been mentioned as a possible toxic to include in this study. Lead is definitely highly toxic , but lead is essentially being regulated out of fuels, even fuels for off-highway vehicles. The additives available over-the-counter for engines that were built to use leaded fuel do not contain lead. While "leaded" gasoline is still available in some areas, the lead content and concentrations of the lead scavengers, ethylene dibromide and ethylene dichloride, are extremely low. Since leaded fuel will not be available in the future, lead and the lead scavengers were not included in this study.

Based on the reasoning outlined above, the toxic compounds for which emission factors should be determined from non-road mobile sources are listed in Table II-4. While these are considered to be the most important compounds for which to obtain emission factors, for some of the compounds there were no measured emission rates available from non-road sources. In those cases, emissions from on-highway vehicles were used to provide at least some indication of emission rates from engines.

REFERENCES FOR SECTION II

II-1 Personal communication between K. Zerafa, US EPA, Ann Arbor MI., and M. Ingalls, Southwest Research Institute, April 10, 1991.

II-2 Adler, J.M., and Carey, P.M., "Air Toxics Emissions and Health Risks from Motor Vehicles", AWMA paper 89-34A.6, presented at the AWMA 82nd Annual Meeting in Anaheim, CA., June, 1989.

were far less when expressed as a percent of total hydrocarbon emissions. Thus, it was decided that the best way to express benzene emissions was a weight percent of total hydrocarbon emissions. Table III-1 presents the benzene emissions from these four studies.

B. Aldehydes

While two aldehydes, formaldehyde and acetaldehyde, are listed in Section II as toxics, the discussion here will include aldehydes in general since some of the early testing of non-road sources measured only total aliphatic aldehydes, expressing the result as formaldehyde using a technique known as the "MBTH Method." While some of the data is almost 20 years old, aldehyde measurements constituted the largest amount of emissions data found of the air toxins considered in this study. AP-42 lists total aldehydes (RCHO), expressed as formaldehyde (HCHO) for several classes of non-road mobile sources. For the most part, these aldehyde emissions were taken directly from the Final Reports for a series of non-road equipment emission measurements made at SwRI in the early nineteen seventies. Work done in 1990 at SwRI on small utility engines for the California Air Resources Board also included aldehyde measurements, as did the tests of diesel forklift engines done for the U.S. Army at SwRI in mid-nineteen eighties. These studies measured individual aldehydes including formaldehyde and acetaldehyde using the DNPH/LC Method. Other than these studies, no aldehyde measurements made specifically on non-road engines were found.

To provide additional information that would be useful in estimating the aldehyde emissions, work done at SwRI over the past 25 years using on-highway vehicle engines was reviewed for aldehyde measurements. Where possible, these aldehyde measurements have been included in study. Tables III-2 to III-7 present the aldehyde emissions by non-road categories. The units of measure have been converted where possible to a consistent set within each category. Sometimes, however, there was insufficient information to convert the measured emission data to a consistent set of units. The aldehyde emissions are presented by individual engine type to the extent possible. Where emissions from a speed and load condition or test cycle are used, the condition or cycle is identified. Where the measurements have been aggregated considering operating time in mode and percent of engines in a category, the values have been designated as "emission factors."

Some aldehyde emission information was found for each of the non-road equipment categories (except marine outboard engines) recommended in the first report for this project. Note, however, that no aldehyde measurements were found for marine slow speed diesel engines. For outboard motors, Reference III-15 contains aldehyde concentrations in ppm, but the calculations to convert these concentrations to mass units and emission factors were not carried out in that study.

C. 1,3-Butadiene

The hydrocarbon 1,3-butadiene was almost never measured in engine exhaust prior to the late nineteen eighties, because the usual sample collection and analytical techniques did not permit the determination of 1,3-butadiene separately from butane. Once 1,3-butadiene was determine to have a high carcinogenic potency, a procedure was developed to selectively measure 1,3-butadiene[III-11]. This procedure is relatively new. Only one study was found with measurements from diesel engines and one study with measurements from non-catalyst gasoline automobiles tested on unleaded gasoline. None of the studies found involved measurement from non-road equipment engines. The gasoline car study was

conducted at SwRI for a commercial firm in 1989. The project consisted of light duty FTP tests on eight non-catalyst cars using unleaded gasoline. We have received authorization to use the data from that study. The 1,3-butadiene emission rates found are presented in Table III-8. These emissions rates may not be usable for all non-road equipment duty cycles. The recommended uses are indicated in the table.

D. Exhaust Particulates

All exhaust particulates, that is, steam, gas turbine, diesel, and gasoline were considered together. The only use of steam boilers in non-road mobile sources is in marine inboard vessels. Exhaust particulate emissions for marine vessels using steam boilers are presently contained in AP-42. These emissions factors are almost 20 years old, and were taken from stationary power plant boiler measurements. Considering, however, that steam powered vessels are becoming fewer in number, the AP-42 emission factors should be sufficient for this study. Marine gas turbine particulate emission factors were estimated from the aircraft gas turbine factors in AP-42.

Particulate measurements on gasoline non-road engines were made at SwRI in the mid-seventies as part of the measurements made for EPA on non-road sources. The emission rates from these studies were determined from measurements made with leaded gasoline which generally contained between 1.5 and 2 grams of lead per gallon. Such fuel is not available commercially today. Because the lead in the exhaust is the predominant exhaust particulate mass when using leaded fuel, the particulate emission rates from these studies should not be used for current emission factors. In particular, the gasoline particulate emission factors for non-road sources listed in AP-42 should not be used. A search of the literature, and test data from projects conducted by the department of Emissions Research at SwRI, revealed only one study which measured particulate from gasoline engines running on unleaded gasoline. This study is the same commercial study which measured 1,3-butadiene. Again, while we are authorized to use the data, we are unable to reference it.

The tests of non-road diesel engines conducted at SwRI in the mid-seventies for EPA do have particulate measurements that are probably still valid to a great extent. These measurements are the basis for the particulate emission factors in AP-42 for agricultural and construction diesel equipment, which are presented in this report without change. The AP-42 diesel emission factors for all non-road source categories were supplemented with particulate measurements from other studies done at SwRI. Tables III-9 to III-13 present the particulate emissions by non-road equipment category.

E. Gasoline Vapors

No measurements of gasoline vapor emissions from non-road equipment could be found. There are evaporative emission factors in AP-42 for general utility engines, farm, and construction equipment. The information in AP-42 was based on the SwRI studies conducted for EPA in the early nineteen seventies[III-10]. A review of that data found that the evaporative emissions were based only on estimates of diurnal losses from automobile tests of that era. To understand the basis for the estimates in AP-42, several paragraphs from Reference 10 describing the reasoning behind the evaporative emission estimates are quoted below.

"Regarding emission of hydrocarbons due to evaporation, it will first be assumed that evaporation of diesel fuel is negligible, although doubtless some spillage losses do occur. Evaporation of gasoline includes spillage losses, running losses from fuel tank and carburetor, "hot soak" losses from fuel tank and carburetor, and diurnal breathing losses from the fuel tank. Spillage and venting during tank filling is probably significant, but analysis of these losses is beyond the intended scope of the subject work. All losses from the carburetor will be neglected due to lack of information, but it is probable that these losses are not large because the carburetors most commonly used are updraft types, located well to the side of the engine and (as much as possible) out of the path of natural convection heat transfer from the engine block.

Although fuel tanks on tractor-type equipment are located directly over the engine in many cases, no information is available on running or hot soak losses from them. It is possible, however, to estimate diurnal breathing losses. In the case of engines used for industrial purposes, the end usage is so varied that an estimate for fuel tank size will have to be made, but better data will be available on this point for tractors and similar equipment. Diurnal losses are primarily functions of fuel vapor pressure, vapor space in the tank, and the range of tank temperatures during the day.

The best available information on gasoline evaporative emissions [7, 8, 9, 10] was developed for passenger cars, and consequently no specific data are given for fuel tanks exposed to direct sunlight or positioned directly over the engine. Comparison of shaded and unshaded storage tank losses has been made, however, indicating that 4 times as much evaporation can occur from an unshaded tank as from a shaded one [10]. This comparison study was based on a 4-week observation period of 300-gallon tanks, each initially full, with removal of 75 gallons of fuel at the end of each week. It seems apparent that the evaporative loss factor for tractor-type equipment and power units having their tanks over the engine and at least partially exposed to sunlight should be higher than that for units having protected fuel supplies. Determining the fractions of power units in each of the two groups (exposed tank and protected tank) will be done later in the report.

The diurnal emission rate which seems most reasonable for automobiles, assuming a fuel RVP (Reid vapor pressure) of 9.0 psi[6], is about (2.0g hydrocarbons)/(gallon tank volume day) [7, 8, 9, 10]. This rate means that a car with a 20 gallon tank would lose 40 g/day, or that one with a 10 gallon tank would lose 20 g/day, and so on. This factor is based on a temperature swing of 25°F to 30°F, with a maximum of 85°F to 90°F. An increase in the maximum temperature would cause greater evaporation, of course, and it is felt that the conditions encountered by tractor fuel tanks would include these higher maximum temperatures. A conservative estimate for unprotected tanks, based on available information [9], would be about (4.0g hydrocarbons)/(gallon tank volume day), or double the rate for a protected tank. Should better information on evaporative losses from off-road equipment become available, the estimates can be revised. For the present, however, the factors of 2g and 4g per gallon tank volume day will be used for protected and unprotected tanks, respectively. Some seasonal and regional variations in

evaporative emissions undoubtedly occur, and attempts to include these variations will be made when emissions impact is estimated."

The references cited in the quote are:

6. Petroleum Products Survey No. 73, U.S. Department of the Interior, Bureau of Mines, January 1972.

7. D. T. Wade, "Factors Influencing Vehicle Evaporative Emissions."

8. P. J. Clarke, et al, "An Adsorption-Regeneration Approach to the Problem of Evaporative Control." SAE Paper No. 670127, 1967.

9. Edwin E. Nelson, "Hydrocarbon Control for Los Angeles by Reducing Gasoline Volatility." Sae Paper No. 690087, 1969.

10. Marvin W. Jackson and Robert L. Everett, "Effect of Fuel Composition on Amount and Reactivity of Evaporative Emissions." SAE Paper No. 690088, 1969.

Other information such as size of gas tank, etc. was used to get evaporative emission estimates for the individual categories of non-road equipment. Since these estimates do not include refueling losses, running losses, or hot soak losses, they probably underestimate the gasoline vapor losses to the atmosphere. Nevertheless, they are presented here because they are all that are available. For ease of reference, the evaporative emissions from AP-42 are included in this report in Table III-14.

F. Iron

No measurements of iron in exhaust particulate of non-road equipment engines were found. Three studies conducted at SwRI were found that determined the percent of iron in exhaust particulate. Two of these studies were chassis dynamometer tests of automobiles. One study was an engine dynamometer test of a heavy duty diesel engine. The iron emissions from these studies are presented in Table III-15. As was the case with the 1,3-butadiene emissions, these iron emissions rates may not be usable for all non-road equipment duty cycles. The recommended uses are indicated in the table.

TABLE III-1 EMISSION FACTORS FOR BENZENE

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle	Benzene % by Wt. of FID HC	Reference Number
DI Diesel Mil Spec diesel	forklift engine	large utility	idle 2% hp @ inter. 100% hp @ rated	2.4 2.7 3.0	III-1
DI Diesel Emisson D2	automobile	large util (cyclic) const.	FTP NYCC	3.1 6.5	III-2
IDI Diesel Emission D2	automibile	large util (cyclic) mar., ag., l.util const.	FTP HFET NYCC	1.5 1.6 2.1	III-2
4 Otto Cycles leaded gasoline	automobiles	large util (cyclic) mar., ag., l.util	FTP SET HFET	3.0 3.4 3.1	III-3
4 Otto Cycles leaded gasoline (12% misfire)	automobiles	large util (cyclic) mar., ag., l.util	FTP SET HFET	1.3 1.3 1.1	III-3
Highway traffic 1973	N.A.		street traffic	3.0	III-4

TABLE III-2. ALDEHYDE EMISSIONS FOR MARINE CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Aldehydes	Formaldehyde	Acetaldehyde	Reference Number
Diesel 2-S blown(mid 1970's) /RR diesel	locomotive	marine diesel med. Speed	Emis. Fac. g/hp-hr g/gal fuel	 0.15 [a] 2.72 [a]			III-7
Diesel 2-S (mid 1970's) /RR diesel	locomotive	marine diesel med. Speed	Emis. Fac. g/hp-hr g/gal fuel	 0.08 [a] 1.56 [a]			III-7
Diesel 4-S turbo (mid 1970's) /RR diesel	locomotive	marine diesel med. Speed	Emis. Fac. g/hp-hr g/gal fuel	 0.16 [a] 3.29 [a]			III-7
Diesel 4-S, DI (mid 1980's)	automotive	marine diesel high speed	HFET g/gal fuel	0.89 [b]	0.53	0.18	III-2
Diesel 4-S IDI (mid 1980's)	automotive	marine diesel high speed	HFET g/gal fuel	0.95 [b]	0.60	0.19	III-2
Diesel 4-S, DI (early 1980's)	truck engin e	marine diesel high speed	HD TRANS g/hp-hr g/gal fuel		0.013 0.19		III-12
4 Gasoline (1970 model) leaded gasoline	automotive	marine otto cycle	HFET g/gal fuel	0.79 [b]	0.69	0.09	III-3
8 Gasoline non-catalyst unleaded gas	automotive	marine otto cycle	FTP g/gal fuel	3.07[b]	1.97	0.52	Commercial Proprietary

[a] "Total Aldehydes" (RHCO) are expressed as formaldehyde (HCHO)
[b] "Total Aldehydes" are sum of the masses of all measured aldehydes.

TABLE III-3. ALDEHYDE EMISSIONS FOR SMALL UTILITY CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Aldehydes	Formaldehyde	Acetaldehyde	Reference Number
Diesel, 4-S IDI Emissions Diesel	non-road engine	small utility	Rated Hp. g/hp-hr g/gal fuel	 0.06 [a] 0.14 [a]			III-10
2-Stroke gasoline	lawn and garden	small utility	Emis. Fact. g/hp-hr g/gal fuel	 2.04 [a] 6.79 [a]			III-5
4-Stroke gasoline	lawn and garden	small utility	Emis. Fact. g/hp-hr g/gal fuel	 0.49 [a] 3.14 [a]			III-5
4-Stroke gasoline	small utility	small utility	Emis. Fact. g/hp-hr g/gal fuel	 0.47 [a] 2.95 [a]			III-5
4-Stroke, side valve, gasoline <225cc	small utility	small utility	J1088 g/hp-hr	0.54 [b]	0.32	0.05	III-6
4-Stroke, OHV gasoline <225cc	small utility	small utility	J1088 g/hp-hr	0.31 [b]	0.19	0.03	III-6
4-Stroke, OHV propane,<225cc	small utility	small utility	J1088 g/hp-hr	0.13 [b]	0.11	0.01	III-6
4-Stroke,side valve/gasoline >225cc	small utility	small utility	J1088 g/hp-hr	0.26 [b]	0.16	0.02	III-6
4-Stroke, OHV gasoline, >225cc	small utility	small utility	J1088 g/hp-hr	0.10 [b]	0.04	0.01	III-6
2-Stroke gasoline	small utility	small utility	J1088 g/hp-hr	1.60 [b]	0.75	0.20	III-6

[a] "Total Aldehydes" (RHCO) are expressed as formaldehyde (HCHO)
[b] "Total Aldehydes" are sum of the masses of all measured aldehydes.

TABLE III-4. ALDEHYDES FROM AGRICULTURAL EQUIPMENT CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Aldehydes	Formaldehyde	Acetaldehyde	Reference Number
8 Diesel engines	non-road engine	agricultural equip. diesel tractor	Emis. Fac. g/hp-hr g/gal fuel	 0.34 [a] 5.44 [a]			III-5
8 Diesel engines	non-road engine	agricultural equip.diesel non-tractor	Emis. Fac. g/hp-hr g/gal fuel	 0.30 [a] 4.63 [a]			III-5
Diesel 4-S DI (id 1980's)	automotive	agricultural equip. diesel all	HFET g/gal fuel	 0.89 [b]	0.53	0.18	III-2
Diesel 4-s IDI (mid 1980's)	automotive	agricultural equip. diesel all	HFET g/gal fuel	 0.95 [b]	0.60	0.19	III-2
4 Gasoline engines (mid 1970's)	non-road engine	agricultural equip. gas tractor	Emis. Fac. g/hp-hr g/gal fuel	 0.30 [a] 3.10 [a]			III-5
4 Gasoline engines (mid 1970's)	non-road engine	agricultural equip. gas non-tractor	Emis. Fac. g/hp-hr g/gal fuel	 0.22 [a] 1.88 [a]			III-5
4 Gasoine engines (1970 model) leaded gasoline	automotive	agricultural equip. gas all	HFET g/gal fuel	 0.79 [b]	0.69	0.09	III-3
8 Gasoline non-catalyst unleaded gas	automotive	agricultural equip. gas all	FTP g/gal fuel	 3.07 [b]	1.97	0.52	Commercial Proprietary

[a] "Total Aldehydes" (RHCO) are expressed as formaldehyde (HCHO)
[b] "Total Aldehydes" are sum of the masses of all measured aldehydes.

TABLE III-5. ALDEHYDES FOR CONSTRUCTION EQUIPMENT CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Aldehydes	Formaldehyde	Acetaldehyde	Reference Number
Diesel	non-road engine	construction tracked tractor	Emis. Fac. g/hp-hr g/gal fuel	 0.17 [a] 2.8 [a]			III-5
Diesel	non-road engine	construction wheeled tractor	Emis. Fac. g/hp-hr g/gal fuel	 0.28 [a] 4.7 [a]			III-5
Diesel	non-road engine	construction wheeled dozer	Emis. Fac. g/hp-hr g/gal fuel	 0.16 [a] 2.6 [a]			III-5
Diesel	non-road engine	construction scraper	Emis. Fac. g/hp-hr g/gal fuel	 0.28 [a] 4.4 [a]			III-5
Diesel	non-road engine	construction motor grader	Emis. Fac. g/hp-hr g/gal fuel	 0.12 [a] 2.0 [a]			III-5
Diesel	non-road engine	construction tracked loader	Emis. Fac. g/hp-hr g/gal fuel	 0.10 [a] 1.7 [a]			III-5
Diesel	non-road engine	construction wheeled loader	Emis. Fac. g/hp-hr g/gal fuel	 0.20 [a] 3.2 [a]			III-5
Diesel	non-road engine	construction non-road truck	Emis. Fac. g/hp-hr g/gal fuel	 0.22 [a] 3.5 [a]			III-5
Diesel	non-road engine	construction roller	Emis. Fac. g/hp-hr g/gal fuel	 0.20 [a] 2.8 [a]			III-5

TABLE III-5 (CONT'D). ALDEHYDES FOR CONSTRUCTION EQUIPMENT CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Aldehydes	Formaldehyde	Acetaldehyde	Reference Number
Diesel	non-road engine	construction misc.	Emis. Fac. g/hp-hr g/gal fuel	 0.20 [a] 3.1 [a]			III-5
Diesel 4-S DI (mid 1980's)	automotive	construction all	NYCC g/gal fuel	0.87 [b]	0.58	0.13	III-2
Diesel 4-S IDI (mid 1980's)	automotive	construction all	NYCC g/gal fuel	2.4 [b]	1.62	0.45	III-2
Diesel 4-S DI (early 1980's)	truck engine	construction all	HD TRANS g/hp-hr g/gal fuel		 0.013 0.19		III-12
Gasoline	non-road engine	construction wheeled tractor	Emis. Fac. g/hp-hr g/gal fuel	 0.25 [a] 2.6 [a]			III-5
Gasoline	non-road engine	construction motor grader	Emis. Fac. g/hp-hr g/gal fuel	 0.29 [a] 2.7 [a]			III-5
Gasoline	non-road engine	construction wheeled loader	Emis. Fac. g/hp-hr g/gal fuel	 0.22 [a] 2.2 [a]			III-5
Gasoline	non-road engine	construction roller	Emis. Fac. g/hp-hr g/gal fuel	 0.26 [a] 2.2 [a]			III-5
Gasoline	non-road engine	construction misc.	Emis. Fac. g/hp-hr g/gal fuel	 0.22 [a] 2.0 [a]			III-5

[a] "Total Aldehydes" (RHCO) are expressed as formaldehyde (HCHO)
[b] "Total Aldehydes" are sum of the masses of all measured aldehydes.

TABLE III-6. ALDEHYDE EMISSIONS FOR NON-ROAD RECREATION VEHICLE CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Aldehydes [a]	Formaldehyde	Acetaldehyde	Reference Number
4-Stroke, 2 cyl 1200cc	motorcycle	non-road recreation vehicle	special chas g/hr g/gal fuel	 2.91 2.62			III-8
4-Stroke, 2 cyl 650cc	motorcycle	non-road recreation vehicle	special chas g/hr g/gal fuel	 1.8 2.50			III-8
4-Stroke, 2 cyl 350cc	motorcycle	non-road recreation vehicle	special chas g/hr g/gal fuel	 2.83 3.84			III-8
4-Stroke, 1 cyl 100cc	motorcycle	non-road recreation vehicle	special chas g/hr g/gal fuel	 0.64 1.95			III-8
2-Stroke, 1 cyl 250cc	motorcycle	non-road recreation vehicle	special chas g/hr g/gal fuel	 3.76 7.02			III-8
2-Stroke, 2 cyl 250cc	motorcycle	non-road recreation vehicle	special chas g/hr g/gal fuel	 3.20 4.76			III-8
2-Stroke, 1 cyl 125cc	motorcycle	non-road recreation vehicle	special chas g/hr g/gal fuel	 3.04 7.44			III-8
2-Stroke, 2 cyl 440cc	snowmobile	non-road recreation vehicle	special map g/hr g/gal fuel	 5.7 6.10			III-9
2-Stroke, 2 cyl 335cc	snowmobile	non-road recreation vehicle	special map g/hr g/gal fuel	 14 13.48			III-9
2-Stroke, 2 cyl 248cc	snowmobile	non-road recreation vehicle	special map g/hr g/gal fuel	 5.3 7.44			III-9

[a] "Total Aldehydes" (RHCO) are expressed as formaldehyde (HCHO)

TABLE III-7. ALDEHYDES FOR LARGE UTILITY CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Aldehydes	Formaldehyde	Acetaldehyde	Reference Number
Diesel 4-S DI (pre 1974) Emissions 2D	non-road engines	large utility cont. power	Rated hp g/hp-hr g/gal fuel	 0.21 [a] 3.8 [a]			III-10
Diesel 4-S IDI (pre 1974) Emissions 2D	non-road engines	large utility cont. power	Rated hp g/hp-hr g/gal fuel	 0.08 [a] 1.1 [a]			III-10
Diesel 2-S (pre 1974) Emissions 2D	non-road engines	large utility cont. power	Rated hp g/hp-hr g/gal fuel	 0.06 [a] 0.99 [a]			III-10
Diesel 4-S DI (mid-1980's) Emissions 2D	forklift engines	large utility cont. power	Rated hp g/hp-hr g/gal fuel		 0.024 0.369	 0.004 0.065	III-1
Diesel 4-S IDI (mid-1980's) Emissions 2D	forklift engines	large utility cont. power	Rated hp g/hp-hr g/gal fuel		 0.001 0.045	 0.001 0.010	III-1
Diesel 4-S DI (mid-1980's) Emissions 2D	automotive	large utility cont. power	HFET g/gal fuel	0.89 [b]	0.53	0.18	III-2
Diesel 4-S IDI (mid-1980's) Emissions 2D	automotive	large utility cont. power	HFET g/gal fuel	0.95 [b]	0.60	0.19	III-2
Gasoline (pre 1974) leaded gas	non-road engines	large utility cont. power	Rated hp g/hp-hr g/gal fuel	 0.31 [a] 3.34 [a]			III-10
Diesel (pre 1974)	non-road engines	large utility cyclic power	Emis. Fac. g/hp-hr	 0.21 [a]			III-10

TABLE III-7 (CONT'D). ALDEHYDES FOR LARGE UTILITY CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Aldehydes	Formaldehyde	Acetaldehyde	Reference Number
Diesel 4-S DI (mid-1980's) Emissions 2D	automotive	large utility cyclic power	FTP g/gal fuel	0.77 [b]	0.48	0.16	III-2
Diesel 4-S IDI (mid-1980's) Emissions 2D	automotive	large utility cyclic power	FTP g/gal fuel	1.78 [b]	1.13	0.32	III-2
4 Gasoline (1970 model) leaded gas	automotive	large utility cyclic power	FTP g/gal fuel	0.79 [b]	0.69	0.09	III-3
Gasoline (pre 1974) leaded gas	non-road engine	large utility cyclic power	Emis. Fac. g/hp-hr	0.22 [a]			III-10
8 Gasoline non-catalyst leaded gas	automotive	large utility cyclic power	FTP g/gal fuel	3.07[b]	1.97	0.52	Commercial Proprietary

[a] "Total Aldehydes" (RHCO) are expressed as formaldehyde (HCHO)
[b] "Total Aldehydes" are sum of the masses of all measured aldehydes.

TABLE III-8. 1,3-BUTADIENE EMISSION FACTORS

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle	1,3-butadiene % of FID HC	Reference Number
Diesel 4-S DI (mid-1980's) Emissions 2D	automobile	marine, high speed diesel, agricultural, construction, large utility	FTP	1.7	III-11
Diesel 4-S IDI (mid-1980's) Emissions 2D	automobile	marine, high speed diesel, agricultural, construction, large utility	FTP	1.5	III-11
8 gasoline non-catalyst unleaded gas	automobile	marine otto cycle, agricultural, construction, large utility	FTP	1.3	commerical proprietary

TABLE III-9. PARTICULATE EMISSIONS FOR MARINE CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Particulates	Reference Number
Steam Boilers residual oil	stationary boilers	marine steam	hoteling lb/1000 gal cruise lb/1000 gal full lb/1000 gal	10.0 20.0 56.5	III-5 (AP-42)
Steam Boilers distillate oil	stationary boilers	marine steam	hoteling lb/1000 gal cruise lb/1000 gal full lb/1000 gal	15 15 15	III-5 (AP-42)
1 G.E. Gas turbine	aircraft	marine gas turbine	hoteling lb/1000 gal cruise lb/1000 gal full lb/1000 gal	0.81 0.34 0.28	III-5 (AP-42)
3 P&WA Gas Turbines	aircraft	marine gas turbine	hoteling lb/1000 gal cruise lb/1000 gal full lb/1000 gal	8.6 3.9 3.4	III-5 (AP-42)
EMD and GE Diesels (1989) /ASTM 2D Fuel	locomotive (line haul)	marine diesel med. Speed	Emis. Fac. g/hp-hr lb/1000 gal	 0.27 12	III-13
EMD and GE Diesels (mid 1980's) /RR diesel	locomotive (switch & line haul)	marine diesel med. Speed	Emis. Fac. g/hp-hr lb/1000 gal	 0.5 20	III-14
Unknown (mid 1980's)	unknown	marine diesel high speed	Emis. Fac. g/hp-hr lb/1000 gal	 0.6 24	III-14
Diesel 4-S DI (early 1980's)	truck engine	marine diesel high speed	HD TRANS g/hp-hr lb/1000 gal	 0.52 17.5	III-12
Diesel 4-S DI (mid 1980's)	automotive	marine diesel high speed	HFET lb/1000 gal	 15.6	III-2
Diesel 4-S IDI (mid 1980's)	automotive	marine diesel high speed	HFET lb/1000 gal	 11.6	III-2
8 gasoline non-catalyst unleaded gas	automotive	marine otto cycle	FTP lb/1000 gal	 1.64	Commercial proprietary

TABLE III-10. PARTICULATES FROM SMALL UTILITY CATEGORY

AVERAGE EMISSION FACTORS FOR ALL ENGINES

(GR/HP-HR)

	HC	CO	NOX	PM
AVEGAGE SMALL ENGINE (1)	37.68	430.33	2.02	0.74
AVERGAE MIDSIZE ENGINE (2)	9.28	352.93	2.03	0.05
AVERAGE LARGE ENGINE (3)	9.60	357.67	2.30	0.21

(1) ASSUMES 95% SIDE VALVE AND 5% OHV

(2) ASSUMES 90% SIDE VALVE AND 10% OHV

3) NO DATA AVAILABLE FOR LARGE OHV ENGINES

RESIDENTAIL EMISSION FACTORS FOR UTILITY ENGINES
(GRAMS PER HP-HOUR)

	4 CYCLE				2 CYCLE			
PRODUCT CATEGORY	HC	CO	NOX	PART	HC	CO	NOX	PART
WALK BEHIND MOWERS	37.7	430	2.02	0.74	208	486	0.29	7.7
RIDING MOWER (FRT ENG)	9.3	353	2.03	0.05				
RIDING MOWER (REAR ENG)	9.3	353	2.03	0.05				
GARDEN TRACTOR	9.6	357	2.3	0.21				
TILLERS	37.7	430	2.02	0.74				
SNOWTHROWERS	37.7	430	2.02	0.74	208	486	0.29	7.7
GENERAL UTILITY	37.7	430	2.02	0.74	208	486	0.29	7.7
SHREDDERS/GRINDERS	37.7	430	2.02	0.74	208	486	0.29	7.7
SPECIALIZED TURF CARE	9.3	353	2.03	0.05				
4-CYC BLOWERS/VACUUMS	37.7	430	2.02	0.74				
4-CYC EDGERS/TRIMMERS	37.7	430	2.02	0.74				
2-CYC EDGERS/TRIMMERS					287	920	0.96	3.6
2-CYC BLOWERS/VACUUMS					283	908	0.96	3.6
CHAIN SAWS					298	699	0.96	3.6

COMMERCIAL EMISSION FACTORS FOR UTILITY ENGINES
(GRAMS PER HP-HOUR)

	4 CYCLE				2 CYCLE			
PRODUCT CATEGORY	HC	CO	NOX	PM	HC	CO	NOX	PART
WALK BEHIND MOWERS	37.7	430	2.02	0.74	208	486	0.29	7.7
RIDING MOWER (FRT ENG)	9.3	353	2.03	0.05				
RIDING MOWER (REAR ENG)	9.3	353	2.03	0.05				
GARDEN TRACTOR	9.6	357	2.3	0.21				
TILLERS	37.7	430	2.02	0.74				
SNOWTHROWERS	37.7	430	2.02	0.74	208	486	0.29	7.7
GENERAL UTILITY	9.3	353	2.02	0.05	208	486	0.29	7.7
SHREDDERS/GRINDERS	9.3	353	2.02	0.05	208	486	0.29	7.7
SPECIALIZED TURF CARE	9.3	353	2.03	0.05				
4-CYC BLOWERS/VACUUMS	9.3	353	2.03	0.05				
4-CYC EDGERS/TRIMMERS	37.7	430	2.02	0.74				
2-CYC EDGERS/TRIMMERS					198	668	0.96	3.6
2-CYC BLOWERS/VACUUMS					283	908	0.96	3.6
CHAIN SAWS					152	513	0.96	3.6

NOTE:EMISSION FACTORS FOR FOUR STROKE ENGINES ARE BASED ON AVERAGE EQUIPMENT HORSEPOWER RATINGS LISTED IN EXHIBIT 2-13, AND ON THE EMISSION FACTORS LISTED IN EXHIBIT 2-17.

EMISSION FACTORS FOR HAND HELD TWO STROKES ARE BASED ON THE HEIDEN ASSOCIATES REPORT TO PPEMA.

EMISSION FACTORS FOR WALK BEHIND TWO STROKES ARE BASED ON CARB TESTING AT SWRI.

TABLE III-11. PARTICULATES FROM AGRICULTURAL EQUIPMENT CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Particulates	Reference Number
8 Diesel engines	non-road engine	agricultural equip. diesel tractor	Emis. Fac. g/hp-hr lb/1000 gal	 1.28 45.7	III-5
8 Diesel engines	non-road engine	agricultural equip.diesel non-tractor	Emis. Fac. g/hp-hr lb/1000 gal	 1.51 51.3	III-5
Diesel 4-S DI (mid 1980's)	automotive	agricultural equip. diesel all	HFET lb/1000 gal	 15.6	III-2
Diesel 4-s IDI (mid 1980's)	automotive	agricultural equip. diesel all	HFET lb/1000 gal	 11.6	III-2
Diesel 4-S DI (early 1980's)	truck engine	agricultural equip. diesel all	7 MODE[a] g/hp-hr lb/1000 gal	 0.53 18.7	III-12
8 Gasoline non-catalyst unleaded gas	automotive	agricultural equip. diesel all	FTP lb/1000 gal	 1.64	commercial proprietary
a: 7 modes of 13 mode cycle weighted per agricultural weighting factors from Reference III-10.					

TABLE III-12. PARTICULATES FOR CONSTRUCTION EQUIPMENT CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Particulates	Reference Number
Diesel	non-road engine	construction tracked tractor	Emis. Fac. g/hp-hr lb/1000 gal	 0.69 25.3	III-5
Diesel	non-road engine	construction wheeled tractor	Emis. Fac. g/hp-hr lb/1000 gal	 1.27 46.5	III-5
Diesel	non-road engine	construction wheeled dozer	Emis. Fac. g/hp-hr lb/1000 gal	 0.41 14.8	III-5
Diesel	non-road engine	construction scraper	Emis. Fac. g/hp-hr lb/1000 gal	 0.79 27.3	III-5
Diesel	non-road engine	construction motor grader	Emis. Fac. g/hp-hr lb/1000 gal	 0.63 22.2	III-5
Diesel	non-road engine	construction tracked loader	Emis. Fac. g/hp-hr lb/1000 gal	 0.66 24.0	III-5
Diesel	non-road engine	construction wheeled loader	Emis. Fac. g/hp-hr lb/1000 gal	 0.81 29.3	III-5
Diesel	non-road engine	construction non-road truck	Emis. Fac. g/hp-hr lb/1000 gal	 0.50 17.7	III-5
Diesel	non-road engine	construction roller	Emis. Fac. g/hp-hr lb/1000 gal	 0.78 24.2	III-5
Diesel	non-road engine	construction misc.	Emis. Fac. g/hp-hr lb/1000 gal	 0.90 30.1	III-5
Diesel 4-S DI (mid 1980's)	automotive	construction all	NYCC lb/1000 gal	 20.3	III-2
Diesel 4-S IDI (mid 1980's)	automotive	construction all	NYCC lb/1000 gal	 14.3	III-2
Diesel 4-S DI (early 1980's)	truck engine	construction all	HD TRANS g/hp-hr lb/1000 gal	 0.52 17.54	III-12
8 Gasoline non-catalyst unleaded gas	automotive	construction all	FTP lb/1000 gal	 1.64	Commercial Proprietary

TABLE III-13. PARTICULATES FOR LARGE UTILITY CATEGORY

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle and Units	Total Particulate	Reference Number
2 Diesel 4-S DI (mid-1980's) Emissions 2D	forklift engines	large utility cont. power	Rated hp g/hp-hr lb/1000 gal	 0.40 16.0	III-1
2 Diesel 4-S IDI (mid-1980's) Emissions 2D	forklift engines	large utility cont. power	Rated hp g/hp-hr lb/1000 gal	 0.12 3.9	III-1
Diesel 4-S DI (mid-1980's) Emissions 2D	automotive	large utility cont. power	HFET lb/1000 gal	 15.6	III-2
Diesel 4-S IDI (mid-1980's) Emissions 2D	automotive	large utility cont. power	HFET lb/1000 gal	 11.6	III-2
8 Diesel (pre 1974)	non-road engines	large utility cyclic power	Emis. Fac. g/hp-hr	 1.00	III-10
Diesel 4-S DI (mid-1980's) Emissions 2D	automotive	large utility cyclic power	FTP lb/1000 gal	 19.0	III-2
Diesel 4-S IDI (mid-1980's) Emissions 2D	automotive	large utility cyclic power	FTP lb/1000 gal	 15.6	III-2
8 Gasoline non-catalyst unleaded gas	automotive	large utility cyclic power	FTP lb/1000 gal	 1.64	commercial proprietary

TABLE III-14 . GASOLINE VAPOR EMISSION FACTORS

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle	Gasoline Vapor g/unit year	Reference Number
None	none	small utility 4-stroke lawn and garden	FTP evap	113	III-5 (AP-42)
None	none	small utility 4-stroke misc.	FTP evap	290	III-5 (AP-42)
None	none	small utility 2-stroke lawn and garden	FTP evap	113	III-5 (AP-42)
None	none	agricultural gasoline (tractor)	FTP evap	15,600	III-5 (AP-42)
None	none	agricultural gasoline (non-tractor)	FTP evap	1,600	III-5 (AP-42)
None	none	construction gasoline wheeled tractor	FTP evap	22,900	III-5 (AP-42)
None	none	construction gasoline motor grader	FTP evap	24,900	III-5 (AP-42)
None	none	construction gasoline wheeled loader	FTP evap	33,900	III-5 (AP-42)
None	none	construction gasoline roller	FTP evap	20,900	III-5 (AP-42)
None	none	construction gasoline misc.	FTP evap	25,400	III-5 (AP-42)

TABLE III-15. IRON EMISSION FACTORS

Engine and Fuel Used	As Tested Use	Recommended Non-Road Category	Test Cycle	Iron % of Tot. Part.	Reference Number
Diesel 4-stroke DI (mid-1980's) Emissions 2D	automobile	marine high speed diesel, agricultural, construction, large utility	FTP HFET NYCC	1.10 0.29 0.67	III-2
Diesel 4-Sroke IDI (mid-1980's) Emissions 2D	automobile	marine high speed diesel, agricultural, construction, large utility	FTP HFET NYCC	0.56 0.47 0.89	III-2
Diesel 4-Stroke	truck engine	marine high speed diesel, agricultural, construction, large utility	Rated hp	0.32	III-12
4 Gasoline non-catalyst leaded gas	automobile	marine otto cycle, agricultural, construction, large utility	FTP SET HFET	2.90 1.84 0.68	III-3

REFERENCES FOR SECTION III

III-1 Dietzmann, H.E., and Lee, T.P., "Emissions Characterization of Diesel Forklift Engines," SAE Paper 841396 presented at the Fuels and Lubricants Meeting in Baltimore, Maryland, October 8-11, 1984.

III-2 Smith, L.R., "Characterization of Exhaust Emissions From Trap-Equipped Light-Duty Diesels," Final report to the California Air Resources Board under contract A5-159-32, dated January 1989.

III-3 Urban, C.M., "Unregulated Exhaust Emissions from Non-Catalyst Baseline Cars Under Malfunction Conditions," Final Report to Environmental Protection Agency under Contract No. 68-03-2884, Task Specifications 4 and 5. Report No. EPA-460/3-81-020, May 1981.

III-4 Mayrsohn, H., et al, "Source Reconciliation of Atmospheric Hydrocarbons, 1974," Atmospheric Environment, Vol. 11, pp 189 (1977).

III-5 "Compilation of Air Pollutant Emission Factors," Volume II, EPA Report No. AP-42, Fourth Edition, September 1985, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

III-6 White, J.J., Carroll, J.N., Hare, C.T., and Lourenco, J.G., "Emission Factors for Small Utility Engines," SAE Paper 910560 presented at the 1991 International Congress & Exposition, Detroit Michigan, February 25-March 1, 1991.

III-7 Hare, C.T., and Springer, K.J., "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines," Final Report Part 1 (Locomotive Diesel Engines and Marine Counterparts) to the Environmental Protection Agency under Contract No. EHS 70-108, EPA Report No. APTD-1490, October 1972.

III-8 Hare, C.T., and Springer, K.J., "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines," Final Report Part 3 (Motorcycles) to the Environmental Protection Agency under Contract No. EHS 70-108, EPA Report No. APTD-1492, March 1973.

III-9 Hare, C.T., and Springer, K.J., "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines," Final Report Part 7 (Snowmobiles) to the Environmental Protection Agency under Contract No. EHS 70-108, EPA Report No. APTD-1496, April 1974.

III-10 Hare, C.T., and Springer, K.J., "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines," Final Report Part 5 (Heavy Duty Farm, Construction, and Industrial Engines) to the Environmental Protection Agency under Contract No. EHS 70-108, EPA Report No. APTD-1494, October 1973.

III-11 Smith, L.R., "Butadiene Measurement Technology," Final Report to the Environmental Protection Agency under Contract 68-03-4044, EPA 460/3/88-005, Work Assignment B-1, August 1988.

III-12 Ullman, T.L., and Hare, C.T., "Emission Characterization of an Alcohol/Diesel-Pilot Fueled Compression-Ignition Engine and Its Heavy-Duty Diesel Counterpart," Final Report to Environmental Protection Agency under Contract 68-03-2884, Task Specification 6. Report No. EPA-460/3-81- 023, August 1981.

III-13 Fritz, S.G. and Cataldi, G.R., "Gaseous and Particulate Emissions from Diesel Locomotive Engines," ASME Paper presented at the 1990 Fall Technical Conference of the Internal Combustion Engine Division, Rockfield, Illinois, October 7-10, 1990.

III-14 Weaver, C.S., "Feasibility and Cost-Effectiveness of Controlling Emissions from Diesel Engines in Rail, Marine, Construction, Farm, and Other Mobile Off-Highway Equipment," Final Report by Radian Corporation for U.S. EPA, Office of Policy Analysis, under Contract 68-01-7288, February 1988.

III-15 Hare, C.T., and Springer, K.J., "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines," Final Report Part 2 (Outboard Motors) to the Environmental Protection Agency under Contract No. EHS 70-108, EPA Report No. APTD-1491, January 1973.

IV. DISCUSSION AND RECOMMENDATIONS

There is so little information available on toxic emissions from non-road sources, that any regional and national impact estimates or exposure estimates calculated from them should be viewed as extremely tentative. One of the tasks of this project was to identify those emission factors that would benefit from updating that can be accomplished over the next four to six months; recommend the specific work to be done; and explain how the work would improve the emission factor value. It should be obvious from the discussions in this report that non-road emission factors for all of the air toxics investigated are inadequate and require more work. There is, however, little that can be done in the next four to six months.

For the long term, a comprehensive plan to acquire the necessary measurements of air toxics from representative non-road equipment is strongly recommended. This plan should include a series of programs similar in nature to the EPA efforts in non-road equipment emissions conducted in the early nineteen seventies, but in keeping with the new emphasis on non-road emissions, be broader in scope. Such a series of projects should include measurements of hydrocarbon speciation in as much detail as possible (not just benzene and 1,3-butadiene), all aldehydes (not just formaldehyde and acetaldehyde), particulate trace metals, particulate organic fraction, Ames bioassay tests, and other unregulated emissions analysis. Equipment tested should include a large number of engines and duty cycles for all categories of non-road sources. There is no question that such a comprehensive series of projects would be costly. Since the decisions which will be made based on these emission factors can possibly result in high total costs to society, the cost to obtain accurate non-road emission factors of air toxics seems justified.

APPENDIX

COMPUTERIZED LITERATURE SEARCH

DIALOG SEARCH (ALL ABSTRACTS EXCEPT SAE)

MEL INGALLS EXT. 2645/BANYAN 08-3426-005 L-0182

I. ABSTRACTS SEARCHED:

File 8:COMPENDEX PLUS_1970-1991/APR
File 35:DISSERTATION ABSTRACTS ONLINE_1861-MAY 91
File 41:POLLUTION ABSTRACTS _ 70-91/MAR
File 40:ENVIROLINE - 70-91/MAR
File 6:NTIS - 64-91/9105B2

II. SEARCH TERMS SET

Set	No. of Items	Description
S1	9882	CONSTRUCTION()EQUIPMENT
S2	962	MARINE()ENGINE? ?
S3	1592	MOTORCYCLE? ?
S4	37	LAWNMOWER? ?
S5	165	OUTBOARD()MOTOR? ? OR OUTBOARD()ENGINE? ?
S6	4281	TRACTOR? ?
S7	4493	AGRICULTURAL()EQUIPMENT
S8	250	RECREATION?()VEHICLE? ?
S9	241	SNOWMOBILE? ?
S10	15301	BENZENE
S11	7300	FORMALDEHYDE
S12	0	ACETALDEHYDR
S13	4807	ALDEHYDE? ?
S14	1692	DIESEL AND PARTICULATE? ?
S15	1226	ACETALDEHYDE
S16	5107	BUTADIENE
S17	266	GASOLINE AND PARTICULAT? ?
S18	797	EVAPORATIVE AND EMISSION? ?
S19	34969	PARTICULATE? ?
S20	21422	1-9/OR
S21	12	20AND10
S22	70	20AND11
S23	23	20AND13
S24	20	20AND14
S25	0	20AND15
S26	23	20AND16
S27	2	20AND17
S28	424	20AND18
S29	95	20AND19
S30	620	21-29/OR
S31	620	S30/ENG
S32	596	RD S31 (unique items)

S33	17	S32 FROM FILE 8
S34	567	S32 FROM FILE 6
S35	0	S32 FROM FILE 35
S36	3	S32 FROM FILE 41
S37	9	S32 FROM FILE 40

FOR FILE 6 (NTIS) ONLY:

S38	162	S34 NOT CERTIFICATION
S39	142	S38 NOT INSULATION
S40	43	S39 AND EMISSION? ?

NOTE: S40 not used.

III. NUMBER OF DOCUMENTS SELECTED FOR MANUAL CHECKING.

142	From	FILE 6
17	From	FILE 8
0	From	FILE 35
3	From	FILE 41
9	From	FILE 40

71 Total document titles chosen for manual perusal

IV. FINAL DOCUMENT SELECTION

A. NTIS DOCUMENTS FROM FILE 6

38/6/51 (Item 51 from file: 6)
1107070 NTIS Accession Number: PB85-124154/XAB
Characterization of Heavy-Duty Motor Vehicle Emissions Under Transient Driving Conditions
NTIS Prices: PC A08/MF A01

39/6/86 (Item 86 from file: 6)
771835 NTIS Accession Number: PB80-175292
Effects of Wetlands on Water Quality in the Devils Lake Basin, North Dakota (Technical completion rept. Jul 76-Sep 79)
NTIS Prices: PC A02/MF A01

39/6/88 (Item 88 from file: 6)
753800 NTIS Accession Number: PB80-128309
A Study of Exhaust Emissions from 1977-1978 Model Year Motorcycles (Technical rept.)
NTIS Prices: PC A08/MF A01

39/6/90 (Item 90 from file: 6)
716554 NTIS Accession Number: PB-296 272/8
Mobile Source Emission Factors for Low-Altitude Areas Only (Final rept)
NTIS Prices: PC A09/MF A01

39/6/1 (Item 1 from file: 6)
1497552 NTIS Accession Number: PB91-108209/XAB
In-Depth Survey Report of Yellow Freight System, Inc., St. Louis, Missouri
NTIS Prices: PC A04/MF A04

39/6/6 (Item 6 from file: 6)
1443265 NTIS Accession Number: PB90-162447/XAB
In Depth Survey Report of Roadway Express, Inc., Toledo, Ohio
NTIS Prices: PC A03/MF A01

39/6/7 (Item 7 from file: 6)
1442890 NTIS Accession Number: PB90-155938/XAB
In Depth Survey Report of Carolina Freight Carriers, Carlisle, Pennsylvania, and York, Pennsylvania
NTIS Prices: PC A03/MF A01

39/6/10 (Item 10 from file: 6)
1428664 NTIS Accession Number: DE89914823/XAB
Schadstoffemissionen aus Motoren von Zweiradfahrzeugen. (Exhaust Gas Emissions from Engines of Motorcycles)
U.S. Sales Only. Portions of this document are illegible in microfiche products.
NTIS Prices: PC A06/MF A01

39/6/11 (Item 11 from file: 6)
1419163 NTIS Accession Number: PB89-229843/XAB
Feasibility and Cost-Effectiveness of Controlling Emissions from Diesel Engines in Rail, Marine, Construction, Farm, and Other Mobile Off-Highway Equipment
(Final rept)
NTIS Prices: PC A07/MF A01

39/6/17 (Item 17 from file: 6)
1344664 NTIS Accession Number: PB88-246392/XAB
Characterization of Diesel Particles in the Atmosphere
(Final rept. 1978-1980)
NTIS Prices: PC A16/MF A01

39/6/25 (Item 25 from file: 6)
1232474 NTIS Accession Number: PB87-127635/XAB
Port Vessel Emissions Model: A Computer Model for Calculating Vessel Air Pollutants. Volume 3. Workbook
(Final rept. Oct 84-Dec 86)
NTIS Prices: PC A04/MF A01

39/6/26 (Item 26 from file: 6)
1232473 NTIS Accession Number: PB87-127627/XAB
Port Vessel Emissions Model: A Computer Model for Calculating Vessel Air Pollutants. Volume 2. User's Manual
(Final rept. Oct 84-Dec 86)
NTIS Prices: PC A19/MF A01

39/6/27 (Item 27 from file: 6)
1232472 NTIS Accession Number: PB87-127619/XAB
Port Vessel Emissions Model: A Computer Model for Calculating Vessel Air Pollutants. Volume 1. Study Report
(Final rept. Oct 84-Dec 86)
NTIS Prices: PC A06/MF A01

39/6/31 (Item 31 from file: 6)
1176534 NTIS Accession Number: PB86-142155/XAB
Size Specific Total Particulate Emission Factors for Mobile Sources
(Final rept)
NTIS Prices: PC A05/MF A01

39/6/34 (Item 34 from file: 6)
1160550 NTIS Accession Number: DE85016410/XAB
Characterization and Mitigation of Organic Vapors
NTIS Prices: PC A02/MF A01

39/6/47 (Item 47 from file: 6)
1102502 NTIS Accession Number: PB85-138279/XAB
Hazardous Air Pollutants: Dry-Deposition Phenomena
NTIS Prices: PC A05/MF A01

39/6/69 (Item 69 from file: 6)
899871 NTIS Accession Number: PB82-169913
Methodology for Estimating Emissions from Off-Highway Mobile Sources for the RAPS Program
(Final rept. Mar-Sep 74)
NTIS Prices: PC A05/MF A01

39/6/74 (Item 74 from file: 6)
872462 NTIS Accession Number: PB82-105099
Inventory of Emissions from Marine Operations Within the California Coastal Waters
(Final rept.)
NTIS Prices: PC A10/MF A01

39/6/77 (Item 77 from file: 6)
866848 NTIS Accession Number: PB81-238305
Compilation of Air Pollutant Emission Factors: Highway Mobile Sources
(Final rept)
NTIS Prices: PC A18/MF A01

39/6/91 (Item 91 from file: 6)
716279 NTIS Accession Number: PB-295 672/0
Mobile Source Emission Factors
(Final rept)
NTIS Prices: PC A17/MF A01

39/6/93 (Item 93 from file: 6)
707432 NTIS Accession Number: AD-A065 623/1
Fouling Effects of Turbine Exhaust Gases on Heat Exchanger Tubes for Heat Recovery Systems
(Research and development rept. for period ending Mar 78)
NTIS Prices: PC A03/MF A01

39/6/101 (Item 101 from file: 6)
628687 NTIS Accession Number: PB-276 102/1
Exhaust Emission Evaluation of Three Caterpillar Tractor D-398 Diesel-Electric Sets
(Final rept.)
NTIS Prices: PC A04/MF A01

39/6/102 (Item 102 from file: 6)
616332 NTIS Accession Number: AD-A046 566/6
U.S. Coast Guard Pollution Abatement Program: Cutter Estimated Exhaust Emissions
(Final rept. Jan-Jun 75)
NTIS Prices: PC A03/MF A01

39/6/103 (Item 103 from file: 6)
615736 NTIS Accession Number: PB-273 503/3
Regional Air Pollution Study: Off-Highway Mobile Source Emission Inventory
(Final rept.)
NTIS Prices: PC A03/MF A01

39/6/106 (Item 106 from file: 6)
605325 NTIS Accession Number: PB-271 697/5
Source Assessment: Harvesting of Grain, State-of-the Art
(Final rept. May-Dec 75)
NTIS Prices: PC A05/MF A01

39/6/107 (Item 107 from file: 6)
605161 NTIS Accession Number: PB-271 486/3
Source Assessment: Mechanical Harvesting of Cotton - State of the Art
(Final rept. Feb 75-Apr 76)
NTIS Prices: PC A06/MF A01

39/6/108 (Item 108 from file: 6)
603164 NTIS Accession Number: PB-271 240/4
Coal Mine Combustion Products: Ingredients of Conveyor Belts
(Rept. of investigations 1977)
NTIS Prices: PC A02/MF A01

39/6/111 (Item 111 from file: 6)
528603 NTIS Accession Number: PB-257 539/7
Effects of Power Plant Emissions on Materials
(Summary rept.)
NTIS Prices: PC A05/MF A01

39/6/114 (Item 114 from file: 6)
501125 NTIS Accession Number: PB-251 555/9
Calculation of Emission Factors for Agricultural Burning Activities
(Final rept.)
NTIS Prices: PC A04/MF A01

39/6/127 (Item 127 from file: 6)
349147 NTIS Accession Number: COM-73-11303/7
Ecology of Small Boat Marinas
(Technical rept.)
NTIS Prices: PC A03/MF A01

39/6/135 (Item 135 from file: 6)
267090 NTIS Accession Number: PB-207 851
An Investigation of Diesel-Powered Vehicle Odor and Smoke. Part III (Final rept.)
NTIS Prices: PC A99/MF A01

39/6/136 (Item 136 from file: 6)
218580 NTIS Accession Number: AD-722 832
Baseline Exhaust Emissions from U. S. Army M54A2 Lds 465 Powered Five-Ton Trucks
(Final rept.)
NTIS Prices: PC A03 MF A01

B. NTIS DOCUMENTS FROM FILE 40 NOT FOUND IN SEARCH OF FILE 6

37/3/2 (Item 2 from file: 40)

0149913 Enviroline Number: *81-002862
PARTICULATE MEASUREMENT-MOTORCYCLE TEST RESULTS,
DANIELSON EUGENE
EPA, MICH,
NTIS REPORT PB80-115983, FEB 78 (9)
THE ORIGINAL DOCUMENT IS AVAILABLE FROM BOWKER

37/3/5 (Item 5 from file: 40)
0108446 Enviroline Number: *76-000075
EXHAUST EMISSIONS FROM UNCONTROLLED VEHICLES AND RELATED EQUIPMENT USING INTERNAL COMBUSTION ENGINES: PART 7-SNOWMOBILES,
HARE, CHARLES T. ; SPRINGER KARL J. SOUTHWEST RESEARCH INST, TEX,
NTIS REPORT PB-238 295, APR 74 (90)
THE ORIGINAL DOCUMENT IS AVAILABLE FROM BOWKER

37/3/6 (Item 6 from file: 40)
0107651 Enviroline Number: *75-007494
SUPPLEMENT NO. 4 FOR COMPILATION OF AIR POLLUTANT EMISSION FACTORS, SECOND EDITION,
EPA REPORT, JAN 75 (70)
THE ORIGINAL DOCUMENT IS AVAILABLE FROM BOWKER

37/3/8 (Item 8 from file: 40)
0032667 Enviroline Number: *74-006046
EXHAUST EMISSIONS & RELATED EQUIPMENT- 3-MOTORCYCLES,
HARE, CHARLES T.; SPRINGER, KARL J.
NTIS REPORT PB-224 884/ 7WP MAR 73 (174)
THE ORIGINAL DOCUMENT IS AVAILABLE FROM BOWKER

37/3/9 (Item 9 from file: 40)
0028908 Enviroline Number: *74-002124
EXHAUST EMISSIONS--OUTBOARD MOTOR,
NTIS REPORT PB-220 399/0 JAN 72 V2 (100)
THE ORIGINAL DOCUMENT IS AVAILABLE FROM BOWKER

C. OTHER DOCUMENTS (FROM FILES 8, 40, 41)

00497399 E.I. Monthly No: EI7511074272 E.I. Yearly No: EI75038627 Title: EXHAUST EMISSIONS FROM FARM, CONSTRUCTION, AND INDUSTRIAL ENGINES AND THEIR IMPACT.
Author: Hare, Charles T.; Springer, Karl J.; Huls, Thomas A.
Corporate Source: Southwest Res Inst
Source: SAE Preprints n 750788 for Meet Sep 8-11 1975, 43 p
Publication Year: 1975
CODEN: SEPPA8 ISSN: 0560-6160
Language: ENGLISH

00876419 E.I. Monthly No: EI7912095864 E.I. Yearly No: EI79046695 Title: EXHAUST

EMISSIONS FROM SMALL ENGINES -- METHODS OF MEASUREMENT, CHARACTERISTIC VALUES, AND USEFULNESS OF DATA.
Author: Hare, C. T.
Corporate Source: Southwest Res Inst, San Antonio, Tex
Source: I Mech E Conf Publ 1978-5, Des and Dev of Small Intern Combust Engines, Douglas, Isle of Man, Engl, May 31-Jun 2 1978. Publ by Mech Eng Publ Ltd for Inst of Mech Eng, London, Engl, 1978 p 203-216
Publication Year: 1978
CODEN: IMEPD4
Language: ENGLISH

33/3/12 (Item 12 from file: 8)
00529739 E.I. Monthly No: EI7604021979 E.I. Yearly No: EI76006563 Title: CONTINUOUS FLOW BIOASSAY METHOD TO EVALUATE THE EFFECTS OF OUTBOARD MOTOR EXHAUSTS AND SELECTED AROMATIC TOXICANTS ON FISH.
Author: Brenniman, G.; Hartung, R.; Weber, W. J. Jr.
Corporate Source: Univ of Ill, Med Cent, Chicago
Source: Water Research v 10 n 2 1976 p 165-169
Publication Year: 1976
CODEN: WATRAG ISSN: 0043-1354
Language: ENGLISH

33/3/17 (Item 17 from file: 8)
00403327 E.I. Monthly No: EI7410059971
Title: COAST GUARD RESEARCH AND DEVELOPMENT PROGRAM FOR THE ABATEMENT OF VESSEL EXHAUST EMISSIONS.
Author: Ard, R. W. Jr.; Walter, R. A.
Corporate Source: Off of Res and Dev, Washington, DC
Source: American Society of Mechanical Engineers (Paper) n 74-ENAs-3 for Meet Jul 29-Aug 1 1974, 9 p
Publication Year: 1974
CODEN: ASMSA4 ISSN: 0402-1215
Language: ENGLISH

36/3/1 (Item 1 from file: 41)
086315 82-06817
Lead Contamination Associated With Snowmobile Trails
Collins, B.J.; Sell, N.J.
Univ. North Carolina-Chapel Hill, Chapel Hill, NC, USA
ENVIRON. RES VOL. 27, NO. 1, pp. 159-163, Publ.Yr: 1982
SUMMARY LANGUAGE - ENGLISH

36/3/2 (Item 2 from file: 41)
035093 75-02214
Exhaust emissions from 2-stroke outboard motors and their impact. SPRINGER, K.J.
Southwest Research Inst.
Automotive Engineering, 82(12): 71, Dec. 1974 Publ.Yr: 1974

36/3/3 (Item 3 from file: 41)

035092 75-02213
Snowmobile engine emissions and their impact.
SPRINGER, K.J.
Southwest Research Inst.
Automotive Engineering, 82(12): 71, Dec. 1974 Publ.Yr: 1974

37/3/1 (Item 1 from file: 40)
0168880 Enviroline Number: *84-000813
FACTORSINFLUENCING THE EMISSIONS OF NITRATED-POLYNUCLEAR AROMATIC HYDROCARBONS (NITRO-PAH) FROM DIESEL ENGINES,
SCHUETZLE DENNIS ; PEREZ JOSEPH M.
(FORD MOTOR CO, MI) AND,; (CATERPILLAR TRACTOR CO, IL)
APCA J, AUG 83, V33, N8, P751 (5)
THE ORIGINAL DOCUMENT IS AVAILABLE FROM BOWKER

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I. SEARCH TERMS

SS 1 /C?
USER:
all construction()equipment
PROG:
SS 1 PSTG (492)

SS 2 /C?
USER:
all marine()engine#
PROG:
SS 2 PSTG (152)

SS 3 /C?
USER:
all motorcycle#
PROG:
SS 3 PSTG (499)

SS 4 /C?
USER:
all snowmobile#
PROG:
SS 4 PSTG (256)

SS 5 /C?
USER:
all tractor#
PROG:
SS 5 PSTG (1756)

SS 6 /C?
USER:
all agricultural()equipment
PROG:
SS 6 PSTG (56)

SS 7 /C?
USER:
all recreational()vehicle#
PROG:
SS 7 PSTG (76)

SS 8 /C?
USER:
all lawnmower#
PROG:
SS 8 PSTG (16)

SS 9 /C?
USER:
all outboard()motor#
PROG:
SS 9 PSTG (27)

SS 10 /C?
USER:
all outboard()engine#
PROG:
SS 10 PSTG (7)

SS 11 /C?
USER:
1 or 2 or3 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
PROG:
SS 11 PSTG (2371)

SS 12 /C?
USER:
all benzene or all formaldehyde or all acetaldehyde or all aldehyde# or
PROG:
CONTINUE ENTERING SS 12.
USER:
all butadiene or all diesel()particulate# or all particulate# or
PROG:
CONTINUE ENTERING SS 12.
USER:
all gasoline()particulate# or all evaporative()emission#
PROG:
SS 12 PSTG (915)

SS 13 /C?
USER:
11 and 12
PROG:
SS 13 PSTG (15)

SS 14 /C?
USER:
prt full 15

II. NUMBER OF DOCUMENTS SELECTED FOR MANUAL CHECKING: 15

III. FINAL DOCUMENT SELECTION

A. SAE PAPERS AND PUBS:

-1-
AN - 860298
TI - Update on the evaluation of diesel particulate filters for underground mining
AU - Lawson, A.; Vergeer, H. C.; Stawsky, A.; Daniel, J. H.; Thimons, E.
OS - Ontario Research Foundation, Sheridan Park, Mississauga, Ontario, Canada; Ontario Research Foundation, Sheridan Park, Mississauga, Ontario, Canada; Engelhard Corp., Specialty Chemicals Div., Edison, NJ; U.S. Dept. of the Interior, Bureau of Mines, Washington, DC; U.S. Dept. of the Interior, Bureau of Mines, Washington, DC
IT - Diesel engines; Diesel exhaust emissions control; Diesel exhaust emissions; Catalytic control; Particulate traps; Filters; Mining equipment; Regeneration; Diesel engine tests; Diesel fuels; Manganese; Sulfates; Sulfur oxides
CC - CONSTRUCTION & INDUSTRIAL MACHINERY, TRACTORS, AND MILITARY EQUIPMENT ,
SO - Society of Automotive Engineers Proceedings No. P-172.
Also published in SAE TRANSACTIONS Vol 95 (1986).
AB - Results of a laboratory assessment of catalyzed ceramic diesel particulate (DPFs) filters are reported. Catalyzed DPFs are shown to substantially reduce diesel particulate emissions, carbon monoxide (CO) and gaseous hydrocarbons as well as particulate ignition temperatures. Sulfate production is discussed in relation to sulfates presently emitted into the mine environment. Field experience is reported on the application of the ceramic diesel particulate filter to control diesel particulate emitted from underground diesel powered vehicles. The vehicle has been operated in mine production service over typical load-haul-dump duty cycles. Field tests have been carried out using the filters assisted with both fuel additive and precious metal catalyst coating techniques. The structural integrity of the filter appears satisfactory with approximately 250 hours of field experience. Both manganese fuel additive and precious metal catalyst coating were shown to provide satisfactory regeneration assist. Exhaust backpressures over a 250-hour test were lower than the original exhaust system comprising an exhaust catalytic purifier and muffler in series.

-2-
AN - 850151
TI - Investigation of the CTO emission control system applied to heavy-duty diesel engines used in underground mining equipment
AU - Mogan, J. P.; Dainty, E. D.; Vergeer, H. C.; Lawson, A.; Westaway, K. C.; Weglo, J. K.; Thomas, L. R.
OS - CANMET, Energy, Mines & Resources Canada; CANMET, Energy, Mines & Resources Canada; Ontario Research Foundation; Ontario Research Foundation; Laurentian University; Falconbridge Nickel Mines Ltd.; Engine Control Systems Ltd.
IT - Diesel exhaust emissions; Diesel exhaust emissions control; Diesel exhaust emissions measurement; Filters; Mining equipment; Particulate traps; Particulates; Tests
CC - CONSTRUCTION & INDUSTRIAL MACHINERY, TRACTORS, AND MILITARY EQUIPMENT
SO - Society of Automotive Engineers Technical Paper No. 850151.
Also published in SAE TRANSACTIONS Vol 94 (1985).
AB - Diesel powered underground mining equipment is presently the most productive and

efficient type of equipment used in underground mining operations. Uncertainties regarding ventilating air levels, which will minimize the risk to health, focus on the role of diesel particulate, both as a toxic agent itself, and as a carrier for other exhaust constituents such as acid gases. This paper describes the application of Catalytic Trap Oxidizer (CTO) Systems for particulate emission control to a test-bed engine and a mining vehicle in service. Testing procedures and results are presented for both laboratory and in-service evaluations. Gaseous and particulate emissions are compared for baseline and CTO-equipped operation and the correlation of laboratory and in-service test results is discussed. The CTO systems demonstrated significant reductions in total particulate emissions, the level of PAH's and Ames mutagenic activity. Some oxidation of SO2 to SO_4^{-2} together with sulphate storage and release was noted in laboratory testing, and an increase in SO_4^{-2} was measured in the mine atmosphere, though well below a threshold limit value of 1 mg/m3 sulphuric acid.

-3-
AN - 850150
TI - Performance of a ceramic diesel particulate trap over typical mining duty cycles using fuel additives
AU - Lawson, A; Vergeer, H. C.; Drummond, W.; Mogan, J. P.; Dainty, E. D.
OS - Ontario Research Foundation, Sheridan Park, Mississauga, Ontario; Energy, Mines & Resources Canada, CANMET, Ottawa, Ontario; Energy, Mines & Resources Canada, CANMET, Ottawa, Ontario .
IT - Ceramics; Diesel exhaust emissions; Diesel exhaust emissions control; Fuel additives; Mining equipment; Particulate traps; Temperature
CC - CONSTRUCTION & INDUSTRIAL MACHINERY, TRACTORS, AND MILITARY EQUIPMENT
SO - Society of Automotive Engineers Technical Paper No. 850150.
Also published in SAE TRANSACTIONS Vol 94 (1985).
AB - The performance of a ceramic wallflow diesel particulate trap is described in relation to regeneration behaviour and emissions reduction from a typical mines heavy duty diesel engine. The use of fuel additives lowered particulate ignition temperature thresholds by approximately 150\mDC, and allowed frequent regeneration of the trap to occur when the engine was operated on a computer controlled engine dynamometer over simulated mine vehicle duty cycles. Thermal stress on the trap during regeneration was minimal. Use of the fuel additive had little effect on changing the trap efficiency for particulate emission reduction which remained generally in excess of 90% efficient. In addition, the fuel additives did not increase sulphate emissions, and reduce Ames mutagenic activity. This approach appears to offer a practical and effective means of diesel emissions control, for most mine LHD vehicles, without the need for additional trap regeneration systems, other than the use of fuel additives.

-4-
AN - 770623
TI - A study of visible smoke reduction from a small two-stroke engine using various engine lubricants
AU - Sugiura, Kensuke; Kagaya, Mineo
OS - Nippon Oil Co., Ltd. (Japan); Nippon Oil Co., Ltd. (Japan)
IT - Exhaust emissions; Engine lubricants; Motorcycles; Two stroke cycle engines; Synthetic lubricants
CC - MOTORCYCLES/SNOWMOBILES

SO - Society of Automotive Engineers Technical Paper No. 770623.
AB - This paper relates the smoke reducing characteristics of two-cycle engine lubricants containing polybutene. Making use of these oils instead of conventional ones, not only smoke but also particulate emissions were reduced, while hydrocarbon concentrations were not affected at all. More than ninety percent of the particulates were unburned lubricant, which account for visible smoke. Diluents such as kerosene and leaner fuel/oil ratios also contributed to the reduction of both smoke and particulates.

-5-
AN - 770258
TI - Unregulated emissions from diesels used in trucks and buses
AU - Springer, Karl J.; Stahman, Ralph C.
OS - Southwest Research Institute; Environmental Protection Agency
IT - Odors; Diesel engines; Exhaust emissions; Diesel smoke; Truck tractors
CC - EMISSIONS
SO - Society of Automotive Engineers Technical Paper No. 770258. Also published in SAE TRANSACTIONS Vol 86 (1977).
AB - A wide variety of exhaust emissions are reported for three diesel engines typically used in heavy-duty intercity truck and intracity bus operation. Particulate, odor, sulfate, sulfur dioxide, and selected non-reactive hydrocarbons were measured in addition to the regulated pollutants from Detroit Diesel 6V-71 and 8V-71TA engines and a turbocharged Cummins 885 cu in research engine. The 855-TC engine was run in standard and a variable injection timing configuration, while the 6V-71 city bus engine was run with two types of injector designs. Emission rates are summarized in terms of grams per unit of fuel consumed and per unit of power output. The data allows direct comparison between engines and engine configurations, as well as a function of engine speed and load condition.

-6-
AN - 740737
TI - Exhaust emissions from 2-stroke outboard motors and their impact
AU - Hare, Charles T.; Springer, Karl J.; Huls, Thomas A.
OS - Southwest Research Institute; Southwest Research Institute; Environmental Protection Agency
IT - Environment; Exhaust emissions; Exhaust emissions control; Tw-o stroke cycle engines
DI - Lincoln, R. H. Outboard Marine Corporation
CC - EMISSIONS
SO - Society of Automotive Engineers Technical Paper No. 740737.
Also published in SAE TRANSACTIONS Vol 83 (1974).
AB - To characterize exhaust emissions from water-cooled 2-stroke outboard motors (the predominant type), four new motors were tested on dynamometer stands. The engines ranged from 4-65 hp in size, and operating conditions were chosen along lines of simulated boat loading. All the measurements were taken at steady-state conditions. Emission concentrations were measured in raw exhaust gas and after the gases had been bubbled through water in a specially constructed tank. Constituents measured included hydrocarbons, CO, CO2, NO, NOx, O2, light hydrocarbons, and aldehydes. Emissions of sulfur oxides (SOx) were estimated on the basis of fuel consumed, and all the exhaust emissions data were used with available information on population

and usage of motors to estimate exhaust emission factors and national exhaust emissions impact. This study did not address the fate of pollutants in either air or water as a function of residence time, nor did it include any assessment of environmental effects due to outboard emissions.

-7-
AN - 740735
TI - Snowmobile engine emissions and their impact
AU - Hare, Charles T.; Springer, Karl J.; Huls, Thomas A.
OS - Southwest Research Institute; Southwest Research Institute; Office of Mobile Source Air Pollution Control Environmental Protection Agency
IT - Exhaust emissions; Two stroke cycle engines; Snowmobiles; Air pollution
DI - De Master, Don Kohler Co.
CC - EMISSIONS
SO - Society of Automotive Engineers Technical Paper No. 740735.
Also published in SAE TRANSACTIONS Vol 83 (1974).
AB - This paper describes a research program on exhaust emissions from snowmobile engines, including both emissions characterization and estimation of national emissions impact. Tests were conducted on three popular 2-stroke twins and on one rotary (Wankel) engine. Emissions that were measured included total hydrocarbons. (paraffinic) hydrocarbons by NDIR, CO, CO2, NO (by two methods), NOx, O2. aldehydes, light hydrocarbons, particulate, and smoke. Emissions of SOx were estimated on the basis of fuel consumed, and evaporative hydrocarbons were projected to be negligible for actual snowmobile operation. During emissions tests, intake air temperature was controlled to approximately 7°C (20°F), and room air at approximately 24°C (75°F) was used for engine cooling. Based on test results and the best snowmobile population and usage data available, impact of snowmobile emissions on a national scale were computed to be minimal.

-8-
AN - 740627
TI - Motorcycle emissions, their impact, and possible control techniques
AU - Hare, Charles T.; Springer, Karl J.; Oliver, William Rogers; Houtman, William H.; Huls, Thomas A.
OS - Southwest Research Institute; Southwest Research Institute; Environmental Protection Agency; Environmental Protection Agency; Environmental Protection Agency
IT - Motorcycles; Exhaust emissions; Exhaust emissions control; Aircooled engines
CC - MOTORCYCLES/SNOWMOBILES
SO - Society of Automotive Engineers Technical Paper No. 740627.
Also published in SAE TRANSACTIONS Vol 83 (1974).
AB - Seven motorcycles, ranging in size from 100 to 1200 cm^3, were tested for emissions characterization purposes. They were operated on the federal seven-mode test procedure (for 1971 and older light-duty vehicles), the federal LA-4 test procedure (for 1972 and later LDVs), and under a variety of steady-state conditions. Four of the machines tested had 4-stroke engines, and the other three had 2-stroke engines. Emissions which were measured included hydrocarbons, CO, CO2, NO, NOx, O2, aldehydes, light hydrocarbons, particulates, and smoke. Emissions of SOx were estimated on the basis of fuel consumed, and evaporative hydrocarbon losses were also estimated. Crankcase "blowby" emissions from one 4-stroke machine were

measured. The impact of motorcycles on national pollutant totals was estimated, based on the test results and information from a variety of sources on national population and usage of motorcycles. In addition, a brief overview of emisson control technology which might be applicable to motorcycles is presented. This discussion indicates that control of hydrocarbon emissions from 2-stroke machines and CO emissions from large motorcycles of both 2-stroke and 4-stroke types are immediate priorities for meeting the tentative 1976 EPA motorcycle emission standards.