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Emission Factor Documentation For AP-42:

Section 3.2.3, Inboard Powered Vessels

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Section 3.2.3, Inboard Powered Vessels

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SECTION 1

INTRODUCTION

The Air Management Technology Branch (AMTB) of the U.S. Environmental Protection Agency (EPA) has the responsibility for maintaining the document Compilation of Air Pollutant Emission Factors, AP-42. AP-42 is widely used by industry and government (including EPA, Department of Defense, and State and local air pollution control agencies) for developing emission inventories and emission estimates. It is increasingly used as a tool in a variety of air quality management applications, including modeling, new source review and control strategy development.

It was brought to the attention of EPA that existing factors (January 1975) for steam and motorships were inadequate for newer vessels and that additional emission data were available on "Inboard Powered Vessels" that warranted an AP-42 revision. Accordingly, the marine vessel combustion emission factors provided in AP-42 were revised incorporating recently acquired combustion emission testing data. This background document provides the methodologies used to expand the existing emission data base and compile the revised marine vessel emission factors. The document concludes with the rationale used to assign a qualitative rating to the emission factors. Raw data summaries are supplied as Appendices.

SECTION 2

DATA COMPILATION METHODOLOGY: STEAMSHIPS AND MOTORSHIPS

The data acquisition required a two phase approach. During the first phase of the effort, literature searches were conducted by both EPA and Engineering-Science, Inc. (E-S). A search of the National Technical Information Service (NTIS) data base was performed by EPA. Concurrently, E-S searched the Lockheed DIALOG, Information Retrieval Services, Inc. DIALOG has more than 170 data bases available on the system and contains in excess of 75 million records or units of information. Using key word indicators to search each system, potential titles were identified and their abstracts screened. Technical documents considered relevant were subsequently obtained.

The second phase of the data acquisition effort involved direct contact between E-S and potential information sources. Governmental sources were the Maritime Administration within the U. S. Department of Transportation and the U. S. Navy. Private sector sources contacted were oil company affiliated research groups, marine surveyors, marine engine manufacturers, select marine vessel owners and operators, and the American Petroleum Institute (API).

Acquired information was categorized as either operational or emission related data. Operation factors included: vessel activity modes, traffic, and classifications necessary to apply the resultant emission factors. (An expanded discussion of operational practices and modes are presented in the main text Section 3.2.3.2.) Emission related data consisted of actual combustion emission measurements and corresponding vessel powerplant performance information. For the data base to be useable, both elements were considered necessary to express or transform emission results from each data source into the same units of measurement. Only results of actual emission measurements were incorporated into the data base.

Criteria pollutant types obtained from the sources presented in this document include oxides of nitrogen (NO_x) expressed as NO_2, carbon monoxide (CO), volatile organic compounds (VOCs), oxides of sulfur (SO_x) expressed as SO_2, and total suspended particulate matter (TSP).

Emission results from each data source were reported in terms of concentration and/or by mass. In certain cases, pollutant concentrations were provided but the exhaust gas flow rate was unknown. Two methods were developed to estimate an exhaust flow rate in order to convert concentration data to a mass emission rate.

The first method utilized tabulated combustion data found in Table D6, Appendix D, of Air Pollution Engineering Manual, AP-40, page 947.[1] This table quantifies the exhaust gas volume produced when combusting various grades of fuel oil. The values are expressed in cubic feet of exhaust gas per pound of fuel oil and are adjusted for combustion with air 40 percent saturated at 60°F (i.e., less than 1 percent moisture by volume) and were thus considered to represent dry standard conditions. The exhaust gas flow rate in dry standard cubic feet per minute is then calculated using the fuel consumption rate,

percent excess air used during combustion, and the appropriate combustion volume from Table D6.[a]

In instances where the excess air or exhaust gas O_2 content was unknown or higher than values listed in Table D6, a second method based on the fuel sulfur content and exhaust gas SO_2 concentration, was used to calculate the exhaust gas flow rate. This method assumes that all the sulfur within the fuel is combusted to SO_2 and that no additional sulfur is introduced into the combustion process. Using these assumptions, the following relationship was derived to calculate the exhaust gas flow rate (dscfm):

$$\text{dscfm} = \frac{\left(\frac{118{,}356}{60}\right)\ (\text{lb/hr fuel rate})\ (\%\ \text{S content})}{\text{ppm } SO_2}$$

The resultant mass emission rate (in lb/hr) can thus be calculated from the pollutant molecular weight, exhaust gas flow rate, and a conversion constant based on the Ideal Gas Law and standard conditions.[b]

The purpose of the AP-42 emission factor compilation is to provide potential users assigned the responsibility to generate emission estimates with a document applicable to data in their presence. Therefore, whenever the data allow, emission factors should be presented in commonly understood units. These units should be the most common values expected to be encountered by the user.

The emission rate data from each source were subsequently converted into the following identical units for compilation:

diesel engines - grams per liter (pounds per 1000 gallons) of fuel or, grams per kilowatt (pounds per horsepower) hour of output.[c]

steam propelled - grams per liter (pounds per 1000 gallons) of fuel or, milligrams per kilojoule (pounds per million BTU) of heat input.[c]

Evaluation of the SO_x measurement data indicated that the measured and theoretical SO_x emissions are essentially equivalent. Therefore, the main text SO_x emission factors were presented in terms of the fuel sulfur content or the theoretical emission rate.

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[a] The excess air used during combustion may be determined from the exhaust gas O_2 content using the relationship defined in Figure 9 of Reference 2.

[b] Standard conditions are for dry gases at 60°F and one atmosphere. The VOC molecular weights used in the calculations were based on VOC speciation results tabulated in Table 1.04-04, 1.04-004, and 2.01-003, of Volatile Organic Compound (VOC) Species Data Manual, Second Edition EPA-450/4-80-015 (Reference 3).

[c] In many cases emission data were only provided in terms of fuel consumed or in terms of power. For those cases, the emissions were converted into both units of measure only if fuel efficiency test data were provided. Data assumptions were minimized in order for the data base to reflect actual measured values.

Subsequent to converting all data to similar units, the emission data were classified according to steamship or motorship, entered into the ES computer, and arranged in order of decreasing size and load.[d]

With the data loaded into the E-S computer, the next step involved selecting appropriate powerplant size and load ranges necessary for final emission data groupings and emission factor determination. The range selection criteria included evaluation of emission data trends and number of test results and powerplants in a given group. This procedure allows for easy identification of substantial changes in emission levels and data base gaps. A minimum of four data points per pollutant (two points for Residual Oil Fired Motorships, Table 3.2.3-5) were required to establish an emission factor for each grouping. If this was not possible, the emission factor was not developed or the data points were averaged as part of an adjacent grouping.

Programming the range selections resulted in data base arrangement by category, calculation of the mean and standard deviation for each category, and a printout of the complete data population and results for each selection range.

TABLE 2.1

EMISSION FACTOR SELECTION CRITERIA

Powerplant (or Engine)	Rated Capacity (HP)	Load (% Full Power)
Motorship (Distillate or Diesel Fuel Fired Diesel Engines)	0-300	0-15, 15-45, 50-75, 75-100
	300-900	0-10, 15-35, 45-75, 75-100
	1000-3600	0-25, 35-55, 75-100
Motorships (Residual or Bunker "C" Fuel Fired Diesel Engines)	0-5000	100
	5000-10,000	100
	10,000-15,000	100
	15,000-20,000	60-100
	20,000-30,000	60-100
Steamships (Residual Fuel Fired Boilers)	All capacities	10-60
		75-100+
Steamships (Distillate or Diesel Fuel Fired Boilers)	All capacities	11, 20-30, 35-60, 95-100

[d]It should be noted that the emission rate data on pleasure craft (see Section 3) were handled separately from the motorship and steamship data.

The resulting motorship and steamship information was statistically analyzed for data exclusion using a log normal probability approach.[4] This approach establishes an acceptability range (expressed as a constant [K] multiplied by the population standard deviation) whereby outliers may be excluded. It is based on selection of an appropriate confidence level (i.e., percent probability that valid data will not be excluded) and use of Table A-2 in Reference 4. A confidence level of 90% was selected for the data sets.

The "final" population (i.e., minus the outliers) was subsequently averaged again to produce the tabulated emission factors.

See Document Appendix A for an example statistical calculation and Appendix B for motorship and steamship data population results. The steamship emission factors in terms of pounds per MM BTU were in some cases calculated using fuel heating values of 150,000 BTU/gal for residual oil and 140,000 BTU/gal gal for distillate oil.

2.1 DATA SOURCES

The following sections describe the individual emission data sources and present sample calculations used to compile the expanded motorship and steamship data base. Sections 2.1.1 through 2.1.8 present the diesel engine sources while Sections 2.1.9 through 2.1.14 present the steam boiler and generator sources.

In order to calculate the steamship emissions in terms of fuel consumption and heat input, it was assumed that the thermal conversion efficiency is constant over load for a given steam boiler or generator. For ease in presentation of data and methodologies, all sample calculations were performed in the reported English units.

The referenced data sources provided organic emission data in terms of total hydrocarbons (i.e., total VOC) only. Therefore, the document entitled Volatile Organic Compound (VOC) Species Data Manual, Second Edition, EPA-450/4-80-015 was used to estimate the methane and nonmethane portion of the total compiled VOC.[3] This document provided volume and weight prcentages associated with each organic constituent produced during residual and distillate fuel oil combustion. It was also used to establish a carbon composite molecular weight necessary to calculate mass emissions from measured concentration.

In each case, the total VOC emissions were compiled prior to computation of the methane/nonmethane fraction. The following organic parameters were assigned to calculate mass emissions and compile the emission factors:

1) Distillate fuel fired boiler: molecular weight per carbon atom = 19.320 g/g-mole, 100% nonmethane VOC

2) Residual fuel fired boiler: molecular weight per carbon atom = 20.556 g/g-mole, 11% methane VOC

3) Distillate (Diesel) fuel fired reciprocating engine (also assumed for residual fuel fired reciprocating engine): molecular weight per carbon atom = 14.012 g/g-mole, 11.6% methane VOC

Particulate size data were not provided by the data sources. Therefore, the revised Section 3.2.3 in AP-42 references generic size specific particulate information compiled in other AP-42 sections.[5]

Following compilation of the information, each data source was assigned a quality rating. Criteria for assignment are defined on page 33 of the AP-42 preparation document.[6] A complete data summary for each data source is provided in Appendix D.

2.1.1 Caterpillar Tractor Company

Caterpillar supplied combustion emission data on select industrial diesel engines which may be considered representative of marine diesel engine applications.[7] Fuel consumption and emission rate data (VOC, NO_x, SO_2, CO, and particulate) were provided in units of gallons/hour and grams/hour respectively, at rating (full load), thus allowing a direct calculation to convert the emission rate to pounds per 1000 gallons and grams/HP/hr. The diesel engines in the data set range in size from 90 - 900 HP.

2.1.1.1 Testing Methods

The data used in this effort from Caterpillar were the result of certification runs performed on actual industrial engines. Test methods for each pollutant were:

VOC - measured using a heated FID (Horiba or Beckman) calibrated with propane. Calculations used carbon balance technique as described in 40 CFR 86 Subpart D

CO - NDIR (Horiba)

NO_x - NDIR (Horiba) plus converter

Dry particulate matter - Opacity meter and a correlation curve from smoke to particulate matter

2.1.1.2 Sample Calculation

A sample calculation demonstrating the direct conversion of the emission rate from reported units to desired emission factor units is provided below.

Given: One 850 HP engine at full load consumes 45.7 gallons/hr of #2 diesel fuel

VOC emissions = 60 g/hour

$$\frac{60 \text{ g/hr}}{850 \text{ HP}} = 0.07 \text{ g VOC/HP/hr}$$

$$\frac{60 \text{ g/hr}}{453.6 \text{ g/lb}} = 0.13 \text{ lb VOC/hr}$$

$$\frac{0.13 \text{ lb VOC/hr}}{45.7 \text{ gal/hr}} = \frac{2.84 \text{ lb VOC}/10^3 \text{ gal}}{} \text{ at 850 HP (100\% load)}$$

2.1.1.3 Data Source Rating

The industrial diesel engine emission data were gathered using approved EPA methodologies for engine emissions certification. However, documentation of tests was limited with most support information provided via telecommunications. Therefore, the data were assigned a B rating.

2.1.2 Colt Industries, Fairbanks-Morse Engine Division

Fairbanks-Morse provided exhaust emission data in terms of grams/HP/hr at full load on three marine diesel engine classifications, a four stroke 520 RPM 650 HP/cylinder engine class, a two stroke 900 RPM 320 HP/cylinder engine class, and a two stroke 900 RPM 180 HP/cylinder engine class.[8] The VOC, NO_x, CO, SO_2, and particulate emission rates provided were reported to be applicable to all size engines within the specified engine classification.

2.1.2.1 Data Source Rating

The methodology used to test the Fairbanks-Morse diesel engine class was essentially consistent with EPA methodology. However, because the emission results were averages over the entire engine classification and not verifiable from the information obtained, a C rating was assigned.

Since C rated data may not be compiled with B rated data, the Fairbanks-Morse information was excluded from the data base.[6]

2.1.3 American MAN Data

There are two sets of data provided by American MAN (manufacturer of large diesel engines). One data set was submitted to Scott Environmental Technology as part of the Appendix to their emission study of California Coastal Waters.[9] This set provided VOC, NO, NO_x, CO, SO_2, and particulate emission data in terms of kg/KW/hr for two, four stroke and two, two stroke engine classifications at 100%, 85%, and/or 60% of full power.

The second set of data was provided by a representative of American MAN[10] NO_x, VOC, and CO exhaust gas concentrations (in ppm) were provided at maximum load for five engine classifications in current production. These data apply as in the case of Fairbanks-Morse to several engine sizes within each classification. Using the same arguments as in the Fairbanks-Morse case, the provided emission rates were applied to each engine type in the class.

2.1.3.1 Testing Methods

The American MAN diesel engine emission data measurements were performed at the manufacturing plant in Germany. Company contacts in the U. S. were unable to obtain information on test methodology and instrumentation without a formal request to German personnel. This process is expected to be too time consuming for this project effort. Emission data provided by the other engine

manufacturers have basically been consistent with EPA mobile source testing methodology. Since American MAN performance test results are compared to U. S. manufacturers, it appears reasonable that the testing instrumentation (engine dynamometer, gaseous analyzers, etc.) are consistent with the U. S. standards.

2.1.3.2 Sample Calculations

Mass emission rates from each currently produced engine were calculated from exhaust gas mass emissions (in kg/KW/hr) provided at full load for each engine classification and a measured exhaust gas emission concentration (in kg/m^3) from a 14,770 rated HP engine provided in the American MAN supplement to the Scott Environmental Technology study. Per discussions with American MAN personnel, it was assumed that measured concentrations would be representative of the exhaust gas concentrations from these currently produced engines.

American MAN also provided the fuel consumption data for projected operation (propulsion) data in terms of g/KW/hr necessary to calculate emission data in $lb/10^3$ gallons or $kg/10^3$ liters. American MAN diesel engine burners have the capability of being fired with #6 fuel oil or #2 diesel fuel.

Scott Environmental Technology American MAN Input:

Engine Classification KSZ 70/125B
(2065 HP/cylinder sizes, four to ten cylinder engines)

Given: at 100% load CO emissions = 2.28 g CO/KW-hr
2.16% S heavy fuel oil #6

Example: four cylinder engine = 2065 x 4 = 8260 HP engine (rated capacity)

$$\frac{2.28 \text{ g/KW-hr CO}}{1.361 \text{ HP/KW}} = 1.67 \text{ g CO/HP-hr}$$

NOTE: Fuel consumption values not provided in this case, therefore $lb/10^3$ gal emission factor not calculated

American MAN Current Production Data

Conversion from ppm to g/hr/cylinder:

Assume the 1.2937 kg/m^3 (at 0°C and 1 atm. dry) exhaust gas density from a 14,770 HP engine (Scott Environmental Technology) applies to the other currently produced diesel engines.

Convert to standard conditions (i.e., 60°F and 1 atm)

$$1.2937 \text{ kg/m}^3 \left(\frac{492°R}{520°R}\right) = 1.2240 \text{ kg/m}^3$$

$$\frac{\text{kg/KW/hr (exhaust gas quantity)}}{(1.2240 \text{ kg/m}^3 \text{ @ } 60°F \text{ dry})} \times \text{rated KW/cylinder}$$

x 35.31 ft^3/m^3 x 1 hr/60 min

= 3.445841×10^{-5} (kg/KW/hr exhaust mass emissions)(rated KW/cyl)

= dscfm/cyl

measured concentration (ppm) x MW x $\frac{\text{dsfm}}{\text{cyl}}$ x 1.58×10^{-7} x 453.6 g/lb

= g/hr/cylinder (where 1.58×10^{-7} = ideal gas constant)

Example: Engine classification 20/27 (100 KW/cylinder for 4 to 9, 12, 14, 16, and 18 cylinder engines)

Given: 120 ppm (actual VOC emissions), 7.4 kg/KW/hr exhaust gas and 212 g/KW/hr fuel consumption at 100% load

120 ppm VOC x 14.012 MW x 7.4 kg/KW/hr x 100 KW/cyl
x 3.445841×10^{-5} g VOC/hr/cylinder = 42.88 g VOC/hr/cylinder

(Molecular weight assumed for heavy fuel oil reciprocating engine combustion, Reference 3)

The emission rate per cylinder applies to each size engine within the engine classification.

Therefore a four cylinder engine (100 KW/cyl x 1.3613 HP/KW[a] x 4 cylinders = 545 rated HP engine) at full (100%) load would have the following VOC emission rate:

$$42.88 \text{ g/hr/cylinder} \times \frac{4 \text{ cylinder}}{545 \text{ HP}} = 0.31 \text{ g VOC/HP/hr}$$

$$212 \text{ g/KW/hr fuel rate} \times \frac{1 \text{ KW}}{1.3613 \text{ HP*}} = 155.7 \text{ g/HP/hr fuel rate}$$

Using a fuel oil #6 density of 8.1 lb/gal

$$155.7 \text{ g/HP/hr} \times \frac{1 \text{ g}}{453.6 \text{ lb}} \times \frac{1 \text{ gallon}}{8.1 \text{ lb fuel}}$$

= 0.0424 gal/HP-hr fuel rate

$$\frac{0.31 \text{ g VOC/HP-hr}}{0.0424 \text{ gal/HP/hr}} \times \frac{1 \text{ lb}}{453.6 \text{ g}} \times 1000 = \underline{16.1 \text{ lb}/10^3 \text{ gal VOC emissions}}$$

2.1.3.3 Data Source Rating

Due to limited documentation of testing and analytical procedures, a rating of C was applied to the American MAN data base.

a) This conversion factor is based on specific metric hp and kw engine designations by American MAN sales brochures.

2.1.4 Cummins Engine Company

The Cummins Engine Company, a manufacturer of marine diesel engines, provided EPA certification data (i.e., emission rates in g/HP/hr and diesel #2 fuel consumption rates in lb/hr) for a series of automotive engine models.[11] While the data were for automotive tests, the information was reported to be applicable to marine engines.

Total hydrocarbon, NO_x, and CO data were provided for 6 engine models at 2, 25, 50, 75, and 100% of full rated power. Emissions in terms of fuel consumption were calculated using a diesel #2 density value of 7.12 lb/gal.

2.1.4.1 Testing Methods

The Cummins engines were tested for EPA certification in 13 different modes and 13 different load cycles. Test procedures and analytical techniques are as follows:

VOC - measured with a FID (Scott) calibrated with propane. Values were expressed as carbon using the carbon balance calculation procedures presented in 40 CFR 86, Subpart D.

NO_x - measured using NDIR (Horiba)

CO - measured using NDIR (Horiba)

2.1.4.2 Sample Calculation

Engine model VT-225

Rated HP = 225

Given: NO_x at 75% power = 7.10 g/HP/hr NO_x
Fuel consumption rate = 70.5 lb/hr at 75% power

$$\frac{70.5 \text{ lb/hr}}{(225 \text{ HP})(0.75)(7.12 \text{ lb/gal diesel \#2 density})} = 0.0587 \text{ gal/HP-hr}$$

$$\frac{7.10 \text{ g/HP/hr}}{0.0587 \text{ gal/HP-hr}} \times \frac{1 \text{ lb}}{453.6 \text{ g}} \times \frac{1000 \text{ gal}}{10^3 \text{ gal}} = \frac{266.7 \text{ lb}/10^3 \text{ gal } (NO_x)}{}$$

2.1.4.3 Data Source Rating

The diesel engine emission results supplied by Cummins were taken from current EPA certification tests of automotive diesel engines. While the tests were reported to follow standard procedures, the necessary information to verify the results was unavailable. Therefore, the data were assigned a B rating.

2.1.5 Detroit Diesel, Allison Division of General Motors

Detroit Diesel, a manufacturer of diesel engines for marine propulsion and electrical generation, provided emission testing data for several electrical generation and propulsion units.[12]

Data applicable to the existing data base consisted of NO and CO emission test results from six engine types. Emissions in terms of fuel consumption were calculated using a #2 diesel density value of 7.02 lb/gal supplied by the manufacturer.

2.1.5.1 Testing Methods

The Detroit Diesel engines were tested using methodology in alignment with the Federal Register. Modal testing was performed on engine dynamometers utilizing non-dispersive infrared continuous analyzers.

2.1.5.2 Sample Calculation

Engine #12V-149T1 at 1900 RPM

Rated HP = 1150, Fuel Consumption = 0.397 lb/HP-hr

Given CO emissions at 100% load (or power) = 6397 g/hr

$$\frac{6397 \text{ g/hr}}{1150 \text{ HP}} = \frac{5.563 \text{ g/HP-hr CO}}{}$$

$$\frac{5.563 \text{ g/HP-hr CO}}{0.397 \text{ lb/HP-hr (fuel consumption)}} \times 7.02 \text{ lb/gal fuel density}$$

$$\times \frac{1 \text{ lb}}{453.6 \text{ g}} \times \frac{1000 \text{ gal}}{10^3 \text{ gal}} = \frac{216.9 \text{ lb/}10^3 \text{ gal CO}}{}$$

2.1.5.3 Data Source Rating

The diesel engine emission results supplied by Detroit Diesel were taken from engine dynamometer modal testing of marine engine and generator set applications. While the tests were reported to follow procedures consistent with EPA methodology, complete data verification was not possible utilizing the supplied data. Therefore, the data were assigned a B rating.

2.1.6 Emission Testing of U.S. Coast Guard Cutters

Scott Research Laboratories, Plumsteadville, PA, conducted emissions tests at various loads on Coast Guard Cutter power plants, and auxiliary generators and boilers.[13] A total of 14 vessels were tested, 13 were propelled with diesel powered engines and one was propelled with fuel oil fired boilers and steam turbines. This section will discuss the 13 diesel engines. The loads were presented in terms of mode of activity (i.e., cruise, idle, full, 2/3, or slow) and/or in some cases, in terms of horsepower output. For entries where only activity modes were presented, assumptions were made as to the percent of rated horsepower per activity mode. These assumptions were based primarily on Table 2.1.6-1 extracted from a U. S. Coast Guard abatement program report.[14] Emissions are presented in terms of lb/1000 pounds of fuel and, in some cases, in terms of lb/hour. The steamship testing was excluded from the data base because load percentages during testing was unknown.

2.1.6.1 Testing Methods

The testing instrumentation and methodology used by Scott are described below:

Particulate matter - EPA Method 5

VOC (Total) - Heated FID (Scott Model 215)

NO and NO_2 - Chemiluminescence (Scott Model 125) analyzer and thermal normal converter

CO - NDIR analyzer (Beckman 315)

TABLE 2.1.6-1

REPORTED COAST GUARD VESSEL DUTY CYCLES[a]

Type of Vessels		Mode	Horsepower (%)
I	WHEC, WMEC, WAGB	Slow	15
		2/3	25
		Cruise	55
		Full	79
II	WPB 95	Slow	32
		Cruise	72
III	WLB, WPB 82	Idle	3
		2/3	22
		Cruise	60
IV	WHEC 327	Idle	Boiler
		Cruise	
		Bull	

[a]Reference 14.

2.1.6.2 Sample Calculation

Vessel: USCGC Chase Class WMEC

Given: Main diesel engine #1 rated at 3600 HP during cruise mode CO emissions = 5.04 lb/1000 pound Navy distillate fuel or 3.87 lb CO/hr

5.04 lb/10^3 lb fuel x 7.12 lb/gal (assumed distillate fuel density) =

35.88 lb CO/10^3 gal

Cruise mode represents 55% of full power from Reference 15

= 3600 HP x 0.55 = 1980 HP output

$$3.87 \text{ lb/hr} \times \frac{453.6 \text{ g/lb}}{1980 \text{ HP output}} = 0.89 \text{ g (CO)/HP/hr}$$

2.1.6.3 Data Source Rating

The thirteen diesel engine powered Coast Guard Cutters were tested following EPA methodology. The field data sheets and calculation procedures were provided to document test results. Therefore, the data source was assigned an A rating.

2.1.7 U. S. Department of Transportation Exhaust Emission Estimates from Water in Fuel Emulsions

A study prepared for the U. S. Department of Transportation evaluated the impact on emissions of increased water in fuel emulsions.[16] Serving as a reference point in each evaluation was a measurement of zero percent water in fuel. These zero water tests were included in the emission factor data base.

2.1.7.1 Test Methods

A series of water in fuel tests were conducted on a Cummins four stroke engine and a Detroit Diesel two stroke unit by Southwest Research Institute. Descriptions of the two engines are presented in Table 2.1.7-1.

The engines were installed in a test cell and connected to an engine dynamometer. The emission tests were conducted using the continuous monitoring systems and methods presented in Table 2.1.7-2. A total of 13 zero percent water emission tests respectively were performed on the Cummins and Detroit Diesel engines.

TABLE 2.1.7-1

ENGINE SPECIFICATIONS FOR
DIESEL ENGINE WATER IN FUEL EMULSION STUDY[a]

Cummins Engine Company, Inc.	General Motors Corporation Detroit Diesel Allison Division
Model: VTA-1710-C800 (VT12-900M)	Model: 12V-149TI (16V-149TI)
Type: Four Stroke Cycle	Type: Two Stroke Cycle
Bore and Stroke: 5.5 x 6	Bore and Stroke: 5.75 x 5.75
No. of Cylinders: 12	No. of Cylinders: 12 (16)
Displacement: 1710 cubic inches	Displacement: 1788 cubic inches
Rated Horsepower: 800 at prop shaft	Rated Horsepower: 900 (1200)
Rated Speed: 2300 RPM	Rated Speed: 1800 RPM

[a]Reference 16.

2.1.7.2 Sample Calculation

Information provided as a result of the test program included:

1. fuel density
2. test run number
3. brake horsepower during test
4. fuel flow (lb/hr)
5. mass emission rates for total hydrocarbons, carbon monoxide, oxides of nitrogen (NO_x)(presented as both g/hr and g/bhp/hr)

Data for g/hr were converted to lb/10^3 gal by the following two step calculation:

Step 1 - conversion of fuel consumption from lb/hr to 10^3 gal/hr

$$\frac{\text{(lb/hr)}}{\text{(lb/gal density)}} = \text{gal/hr}$$

$$\text{gal/hr} \times \frac{10^3 \text{ gal}}{1000 \text{ gal}} = 10^3 \text{ gal/hr}$$

Step 2 - conversion of g/hr to lb/10^3 gal

$$\frac{\text{lb/hr}}{10^3 \text{ gal/hr}} = \text{lb/}10^3 \text{ gal}$$

Test Application

Given: Test Run #171
436 HP output
182 lb/hr diesel fuel flow
7.12 lb/gal assumed #2 diesel density
0.28 g/HP/hr total hydrocarbon emissions

$$\frac{182 \text{ lb/hr diesel}}{(7.12 \text{ lb/gal})(10^3)} = 0.026 \times 10^3 \text{ gal/hr}$$

$$0.28 \text{ g VOC/HP/hr} \times 436 \text{ HP} = 122 \text{ g VOC/hr}$$

$$\frac{122 \text{ g/hr}}{(454 \text{ g/lb})(0.026 \times 10^3 \text{ gal/hr})} = \underline{10.3 \text{ lb VOC/}10^3 \text{ gal}}$$

TABLE 2.1.7-2

TESTING METHODS AND INSTRUMENTATION FOR DIESEL ENGINE

WATER IN FUEL EMULSION STUDY[a]

Emission	Detection Method	Instrument	Range	Nominal Concentration
Carbon Monoxide (S/N AIA-23)	NDIR	Horiba OPE-15	1	0-1000 ppm CO
			2	0-3000 ppm CO
			3	0-6000 ppm CO
Carbon Monoxide (S/N 15395)	NDIR	Horiba OPE-15	1	0-16% CO_2
			2	0-6% CO_2
			3	0-2% CO_2
Oxides of Nitrogen (S/N LOAR-9691-110)	CL	TECO 10	1	0-250 ppm
			2	0-1000 ppm
			3	0-2500 ppm
Hydrocarbons[b] (S/N 10010)	FID	Beckman 402	1	0-500 ppm C
			2	0-1000 ppm C
			3	0-5000 ppm C
Oxygen (S/N 271001)	Polaro-graphic	Beckman OM-11EA	1	0-25% O_2
			2	0-5% O_2

[a]Reference 16.

[b]Hydrocarbon analyzer calibrated with propane. H/C ratio in mass emission calculation was 1.8 to 1.

2.1.7.3 Data Source Rating

The two diesel engines used in the fuel emulsion study were tested according to methods consistent with EPA continuous analyzer methodology. The referenced document thoroughly discusses the emission calculation and analyzer calibration procedure. Based on testing methodology and documentation, a rating of A was assigned to these data.

2.1.8 U.S. Coast Guard Pollution Abatement Program: A Preliminary Report on the Emissions Testing of Boat Diesel Engines

Data were taken from the mass emission rate summaries of a report prepared by the Transportation Systems Center.[17] Reported information taken from the table included the engine horsepower at the time of the test and the emission rates for oxides of nitrogen and total hydrocarbons reported as grams per brake horsepower per hour (g/bhp/hr). Data were reported for tests performed on four different engines, each rated at 200 HP. Since the rated engine size

was known, engine horsepowers at specific test conditions were converted to percent of load. A total of 26 emission data points for a 200 HP diesel engine operating at a variety of load conditions was entered into the data base.

2.1.8.1 Test Methods

The emission tests were conducted on three General Motors (GMC-71) and a Cummins (VT-330) diesel engines. Tests were conducted using an engine dynamometer as a function of engine load. The GM engines were rebuilt prior to testing while the Cummins engine was in a used condition.

Each engine was tested in six operating modes ranging from idle (600 rpm, zero bhp) to full rated capacity (2,000 rpm, 185 bhp). Two test runs were conducted at each engine load for a total of 12 test runs per engine. The following continuous monitoring systems were used to perform these emission tests.

Pollutant	Continuous Testing Method
Carbon Monoxide and Carbon Dioxide	Nondispersive infrared
Total Hydrocarbons	Total hydrocarbon analyzer (carbon balance technique used to calculate VOC mass emission rate)
Oxides of Nitrogen	Chemiluminescence
Oxygen	Paramagnetic
Smoke	Ringelmann chart and opacity meter

Each continuous analyzer was zeroed and calibrated both before and after each test run.

Reported in the summary of information but not included in the evaluation was mass emission rates for the same pollutants in units of pounds per hour. The data source did not adequately report fuel consumption during tests so no calculation was made of corresponding pounds of pollutant per unit fuel usage.

2.1.8.2 Data Source Rating

The diesel engine emission data were obtained from engine dynamometer tests consistent with EPA mobile testing methodology. However, only minimal documentation of tests data was available. Therefore, a B rating was assigned to this data source.

2.1.9 Nitrogen Oxide Monitoring on a British Petroleum Tanker

Scott Environmental Technology conducted NO_x emission testing during cargo offloading of a British Petroleum tanker.[18] The tanker was equipped with two oil fired main boilers which supply steam to power the cargo unload operation. The maximum steam production rate and steam heat rate output from each boiler is 6395.8 kg (141,000 lb) per hour of steam and 102.2×10^9 J (96.9×10^6 BTU) per hour respectively.

2.1.9.1 Test Methods

Emission tests were conducted on the starboard boiler using a Scott Model 125 chemiluminescent nitrogen oxide analyzer. The analyzer was connected to the sample point by a 30.5 m (100 ft) temperature controlled, teflon sampling line. The temperature was regulated to 383°K (230°F) to maintain the sample above the moisture dew point through the entire sampling system up to the NO_x converter. At the converter a valve assembly provided the option of running the sample through the converter to convert NO_2 to NO giving total NO_x or bypassing the converter to measure only NO (NO_2 by difference). Emission data were averaged on a time weighted basis and tabulated hourly and, in some cases, every half hour over a cargo unloading period of 27 hours. Emissions were recorded in terms of ppm and lb/bbl of fuel.

2.1.9.2 Sample Calculations

The following two step calculation procedures demonstrates the technique used to arrive at NO_x emission rates.

1. Boiler Heat Input Calculation

   Given: Fuel Oil heat content by analysis: 18,450 BTU/lb Boiler
   Boiler thermal efficiency: 70% (reported in reference)
   Maximum boiler heat output: 96.9×10^6 BTU/hr

   $$\left(\frac{96.9 \times 10^6 \text{ BTU/hr heat output max.}}{70\% \text{ thermal efficiency}}\right)$$

   $= 138.5 \times 10^6$ BTU/hr Maximum Heat Input per Boiler

2. NO_x Emission Calculation

   Given: Total Fuel Rate = 89 bbl/2 hr,
   NO_x emission = 3.01 lb NO_x/bbl

   $$(3.01 \text{ lb } NO_x/\text{bbl}) \times \left(\frac{1 \text{ bbl}}{42 \text{ gal}}\right) \times (1000 \text{ gal}) = 71.67 \text{ lb } NO_x/10^3 \text{ gal}$$

18,450 BTU/lb (heating value) x 8.1 lb/gal (assumed fuel oil #6 density from Reference 7) x 1000 gal/10^6 BTU = 149.445 x 10^6 BTU/10^3 gal

$$\frac{71.67 \text{ lb}/10^3 \text{ gal}}{149.445 \times 10^6 \text{ BTU}/10^3 \text{ gal}} = \frac{0.48 \text{ lb } NO_x/10^6 \text{ BTU}}{}$$

2.1.9.3 Data source Rating

The British Petroleum data were derived by EPA approved testing methodologies, including Method 7 validation runs. Raw NO_x data were also provided in the form of strip charts with calibration curves. As a result, these data were assigned on A rating.

2.1.10 Stack Gas Analysis of Steamship Boiler Propulsion Plant

CE-Power Systems of Windsor, CT, conducted shipboard emission tests of a two boiler propulsion unit rated at 23,863 KW (32,000 hp). The port boiler rated at 156 x 10^9 J (148 million BTU) per hour was tested over a five day period.[2] During the testing, the boiler was fired on No. 6 fuel oil at various loads (percentages of full power) and excess air levels.

2.1.10.1 Test Methods

A summary of test equipment and procedures are presented in Table 2.1.10-1. Actual test conditions are presented in Table 2.1.10-2. Test results of all pollutants were recorded measured in actual ppm and ppm corrected to 3 percent O_2.

2.1.10.2 Sample Calculations

To calculate the pollutant mass emission rate in lb/hr from the ppm calculation, the excess air calculation method (See Section 2) was employed.

Given: 10/27/76 test date
Boiler load 109%
Excess air 17%
Average fuel oil heating value = 18,445 BTU/lb
CO concentration = 5 ppm actual
Boiler rated (at 100% load) = 148 x 10^6 BTU/hr

148 x 10^6 BTU/hr x 1.09 = 161 x 10^6 BTU/hr heat input @ 109% load

$$\frac{161.32 \times 10^6 \text{ BTU/hr}}{18{,}445 \text{ BTU/lb}} = 8746 \text{ lb/hr fuel rate}$$

$$\frac{8746 \text{ lb/hr fuel}}{60} = 145.8 \text{ lb/min fuel rate}$$

TABLE 2.1.10-1

SUMMARY OF TEST EQUIPMENT AND PROCEDURES FOR A 32000 HP STEAM PROPULSION PLANT[a]

Measured Quantity	Description of Test Equipment	Method Employed
O_2	Teledyne O_2 Analyzer	Electrochemical Cell
CO	Ecolyzer CO Analyzer	Electrochemical Cell
NO_x	Dynasciences NO_x Analyzer	Electrochemical Cell
SO_2	Scott Gas Sampling Train	EPA Method 6[b]
SO_3	Scott Gas Sampling Train	EPA Method 8[b]
H_2O	Scott Gas Sampling Train	EPA Method 4[b]

[a]Reference 2.
[b]Code of Federal Regulations, Title 40, Chapter 1, Part 60.

TABLE 2.1.10-2

SUMMARY OF ACTUAL TEST CONDITIONS FOR A 32000 HP STEAM PROPULSION PLANT[a]

Test Condition Number	Actual Boiler Load at Full Power	Actual Excess Air %	Sample Numbers[b]	Test Date
1	11 (In Port)	192	8,9,10,11,12	10/26/76
2	27	40	40,41,42	10/29/76
3	29	98	43,44,45	10/29/76
4	44	17	38,39	10/29/76
5	46	24	34,35,37	10/29/76
6	44	33	36	10/29/76
7	79	10	28,29,30	10/28/76
8	78	16	31,32,33	10/29/76
9	95	5	13,14,15	10/27/76
10	95	9	5,6,7	10/25/76
11	94	16	1,2,3,4	10/25/76
12	94	22	16,17,18	10/27/76
13	111	5	25,26,27	10/28/76
14	110	9	22,23,24	10/28/76
15	109	17	19,20,21	10/27/76

[a]Reference 2.
[b]45 total samples.

5 ppm CO x 28 MW x 216.2 dscf/lb
(Table D6 of AP-40 interpolated for 17% excess air and # 6 fuel oil)

x 1.58 x 10^{-7} (ideal gas law constant) x 145.8 lb/min (fuel rate)

= 0.697 lb CO/hr or 316.2 g CO/hr

8746 lb/hr fuel rate
8.1 lb/gal (assumed fuel density from Reference 20)

= 1079.75 gal/hr fuel rate

$$\frac{0.697 \text{ lb CO/hr}}{1079.75 \text{ gal/hr fuel}} \times 1000 = 0.646 \text{ lb CO}/10^3 \text{ gal}$$

$$\frac{0.697 \text{ lb CO/hr}}{161.32 \times 10^6 \text{ BTU/hr}} = 0.004 \text{ lb CO}/10^6 \text{ BTU}$$

2.1.10.3 Data Source Rating

The marine boiler used in the reliability study followed methodologies consistent with EPA procedures. However, complete data validation was not possible due to limited documentation in the reference. The information source was therefore assigned a rating of B.

2.1.11 Scott Environmental Technology Oil Tanker Testing

Scott Environmental Technology conducted NO_x, CO, SO_2, and total hydrocarbon emission tests on boilers from three tanker steam powerplants during cargo offloading.[9] In addition, one of these vessels (ARCO Sag River) was testing at various operating modes while in transit from Long Beach to San Francisco, CA.

2.1.11.1 Test Methods

Both the cargo offloading and intransit tests were performed using continuous analyzers for NO_x, CO and total VOC, along with EPA Method 8 testing for SO_2 and H_2SO_4. Test procedures utilized are presented in Table 2.1.11. Figure 2.1.11 illustrates the instrumentation system used to analyze the gathered sample. No. 6 fuel consumption and O_2 content measurements were taken during the testing period.

2.1.11.2 Sample Calculations

To calculate emissions in terms of lb/10^3 gal or lb/10^6 BTU required use of one of the methods discussed in Section 2. The sulfur content method was used if the boiler excess air was higher than 100% while the method utilizing Table D6 of AP-40 was used if the excess air was less than 100%.

TABLE 2.1.11

SUMMARY OF TEST PROCEDURES OIL TANKER EMISSION TESTING[a]

Gas Constituent	Test Procedure
SO_2 and H_2SO_4	EPA Method 8
NO and NO_x	Philco-Ford Chemiluminescent continuous analyzer
CO	Ecolyzer Electrochemical continuous analyzer
Hydrocarbons	Scott Heated Flame Ionization continuous analyzer
Oxygen	Beckman Polarographic continuous analyzer
CO_2	Orsat

[a]Reference 9.

In transit testing of Arco Sag River Tanker

Given: 18000 HP steam turbine (2 boilers)
Transition mode (harbor to sea lane)

6.6% O_2, 4% excess air, 227.5 ppm NO_x at 59.9% load

Two boiler Propulsion unit, 106.8 tons No. 6 fuel oil/day rated capacity
15.71 bbl/hr (660 gal/hr) fuel consumption rate at 59.9% load

8.1 lb/gal, 18408 BTU/lb (No. 6 fuel oil density and heating value
Reference 20)

Rated capacity of boiler in terms of BTU:

106.8 T/day fuel x 2000 lb/T x 1 day/24 hours
= 8900 lb/hr fuel rated capacity

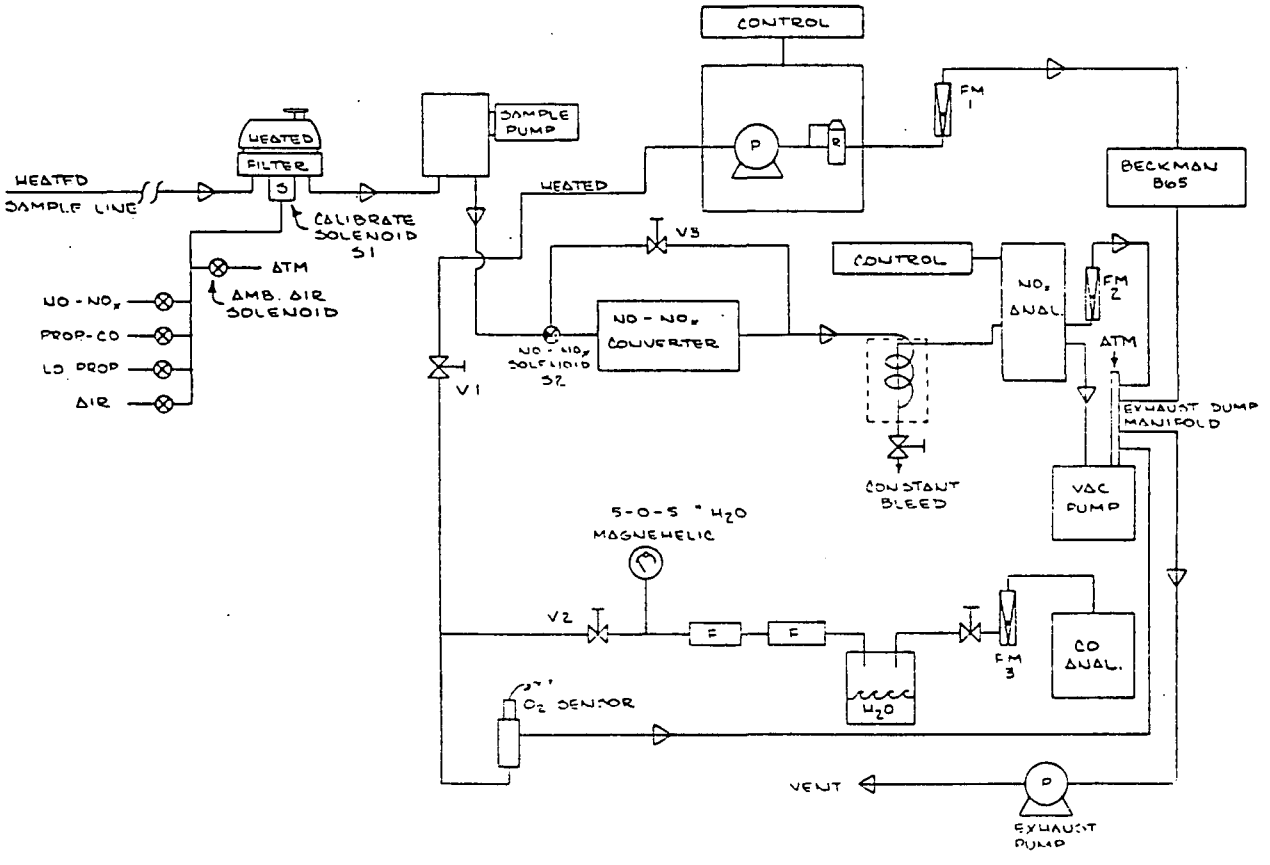
18408 BTU/lb (heating value) x 8900 lb/hr fuel
= 163.83 x 10^6 BTU/hr rated capacity propulsion unit

Calculation of NO_x mass emission rate

227.5 ppm NO_x x 46 MW (NO_x as NO_2) x 1.58 x 10^{-7} (ideal gas constant)

x $\frac{268.3 \text{ dscf}}{1\text{b fuel}}$ (No. 6 fuel oil at 44% excess air, Table D6, AP-40)

FIGURE 2.1.11. MARINE TESTING SYSTEM AND OIL TANKER EMISSION TESTING[a]



[a]Reference 9.

x 660 gal/hr fuel

x 8.1 lb/gal fuel density x 1 hr/60 min = 39.53 lb NO_x/hr

$$\frac{39.53 \text{ lb } NO_x/hr}{163.83 \times 10^6 \text{ BTU/hr rated capacity} \times (0.599 \text{ load})} = 0.403 \text{ lb}/NO_x \ 10^6 \text{ BTU}$$

$$\frac{39.53 \text{ lb } NO_x/hr}{660 \text{ gal/hr fuel}} \times 1000 = 59.9 \text{ lb } NO_x/10^3 \text{ gal}$$

2.1.11.3 Data Source Rating

A review of submitted information indicated that the oil tanker boilers were sampled utilizing essentially EPA approved methodology. However, a B rating was assigned to this data source due to the lack of complete traceability.

2.1.12 Land Based Naval DLG-9 Steam Generator Testing

Emissions testing of a land based DLG-9 (naval destroyer) steam generator was conducted by three Naval laboratories within the Naval Ship Research and Development Center.[21] NO_x, SO_2 and particulate emissions were tested using electrochemical type continuous analyzers in addition to EPA wet chemistry.[d] Particulate emissions were also measured using EPA wet chemistry. Tests were conducted while the steam generator fired Navy Distillate (ND) or Navy Special Fuel Oil (NSFO) at full power, 35% load (simulating maneuvering or harboring), and 11% load (simulating hoteling). Results were tabulated in terms of lb pollutant per million BTU.

2.1.12.1 Test Methods

Selection of site and preparation of DLG-9 were performed according to EPA Method 1. Site location was approximately eight equivalent diameters beyond any major disturbance, such as a bend, flange, etc. This location was selected to ensure a stable flow pattern. A prototype air pollution monitoring system for source emissions was assembled for use in obtaining the shipboard air pollutant emission measurements. Elements of the prototype system included flow meters and a heated sample line maintained at 394°K (250°F). Test procedures included EPA wet chemistry Method 6 for SO_2 and EPA Method 7 for NO_x.

2.1.12.2 Sample Calculations

The following calculations present the methodology used to estimate emission factors from this data base using both Navy Distillate and Special Fuel Oil.

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[d]For specific test run where a pollutant was measured simultaneously using both testing methods presented above, the resultant emissions were averaged and allocated as a single entry to the data base.

1. Generator firing Navy Distillate Fuel

Given: Rated power 257 x 10^6 BTU/hr
0.29 lb $NO_x/10^6$ BTU @ 100% load (full power) Navy Distillate
heating value = 19,300 BTU/lb

7.12 lb/gal (assumed distillate or #2 diesel fuel density)

$$19{,}300 \text{ BTU/lb} \times 7.12 \text{ lb/gal} \times \frac{1000 \text{ gal}}{1 \times 10^6 \text{ BTU}} = \frac{137.74 \times 10^6 \text{ BTU}}{1000 \text{ gallons}}$$

$$0.29 \text{ lb } NO_x \ 10^6 \text{ BTU} \times 137.74 \times 10^6 \text{ BTU}/10^3 \text{ gal} = \underline{39.9 \text{ lb } NO_x/10^3 \text{ gal}}$$

2. Generator Firing Navy Special Fuel Oil

Given: Rated power = 249 x 10^6 BTU/hr
Emissions = 0.6103 lb TSP/10^6 BTU @ 11% load
NSFO heating value = 18,700 BTU/lb
Assumed NSFO or fuel oil #6 density (Reference 20)
= 8.1 lb/gal

$$18{,}700 \text{ BTU/lb} \times 8.1 \text{ lb/gal} \times \frac{1000 \text{ gal}}{1 \times 10^6 \text{ BTU}} = \frac{151.47 \times 10^6 \text{ BTU}}{1000 \text{ gallons}}$$

$$0.6103 \text{ lb TSP}/10^6 \text{ BTU} \times \frac{151.47 \times 10^6 \text{ BTU}}{1000 \text{ gallons}} = \underline{92.4 \text{ lb TSP}/10^3 \text{ gal}}$$

2.1.12.3 Data Source Rating

The land based naval steam generator was tested using methods consistent with EPA continuous analyzer and wet chemistry methodologies. However, the reported results in pounds of pollutant per million BTU were not completely verifiable from the reference document and thus a B rating was assigned.

2.1.13 Naval Shipboard Testing of the USS Kawishiwi, USS Juneau, USS Forrest Sherman, and USS L.Y. Spear

Shipboard emission tests were conducted on the Navy distillate fired steam propulsion boilers on these vessels.[19,22-23] The Juneau and Kawishiwi were tested for NO_x, SO_2, CO and particulate matter while the latter vessels were tested for total hydrocarbons in addition to the other four pollutants. Results were presented in terms of ppm lb/MMBTU and, in some cases, lb/hr.

2.1.12.1 Test Methods

The test methods varied between ships and are listed below for each ship.

a. USS Kawashiwi and Juneau
SO_2 and NO_x - Theta Sensors, Inc. continuous analyzer
CO and CO_2 - MSA NDIR analyzer
Particulate matter - Method 5

b. USS Forrest Sherman
Particulate matter - Method 5 for one hour
Total VOC - heated probe to FID, results reported as ppm carbon
SO_2, NO_x, CO - "continuous gas analyzers" of unknown type

c. USS L.Y. Spear

Particulate matter - EPA Method 5
SO_2 - Pulse fluorescence detector
NO_x - Chemiluminescence
VOC (total) - heated FID, values reported as ppm methane
CO and CO_2 - NDIR

2.1.13.2 Sample Calculation

For cases where only ppm values were tabulated, the corresponding mass emission rates were determined using the fuel sulfur content method presented in Section 2.

Given: Emissions = 40 ppm SO_2 and 20 ppm NO_x @ 20% load (hoteling)
Navy Distillate heating value = 19,300 BTU/lb (Reference 21)
Navy Distillate sulfur content = 1.02% sulfur
Fuel burning rate = 26.9×10^6 BTU/hr @ 20% load
Assumed Navy Distillate density = 7.12 lb/gal

Exhaust gas volume at 60°F, dry, 1 atm

$$= \left(\frac{118{,}356}{60 \text{ min/hr}}\right) \times \left(\frac{26.9 \times 10^6 \text{ Btu/hr}}{19{,}300 \text{ BTU/lb}}\right) \times \left(\frac{1.02\% \text{ S fuel}}{40 \text{ ppm } SO_2}\right)$$

= 70,109 dscfm exhaust volume @ 20% load

20 ppm NO_x x 46 (MW NO_2) x 70,109 dscfm
x 1.58×10^{-7} (ideal gas constant) = 10.19 lb NO_x/hr

$$\frac{10.19 \text{ lb } NO_x/\text{hr}}{26.9 \times 10^6 \text{ BTU/hr at 20\% load}} = \frac{0.38 \text{ lb } NO_x/10^6 \text{ BTU}}{}$$

$$19{,}300 \text{ BTU/lb fuel heating value} \times 7.12 \text{ lb/gal fuel density} \times \frac{1000}{1 \times 10^6}$$

$$= 137.42 \ \frac{10^6 \text{ BTU}}{1000 \text{ gals}}$$

$$0.38 \text{ lb}/10^6 \text{ BTU} \times 137.42 \ \frac{10^6 \text{ Btu}}{1000 \text{ gal}} = \frac{52.2 \text{ lb } NO_x/10^3 \text{ gal}}{}$$

2.1.13.3 Data Source Rating

The use of Method 5 for particulate matter sampling and the various continuous analyzers for the gaseous pollutants are consistent with EPA methodologies. However, the information provided was insufficient to allow for validation of test results. Therefore, all the data were given a B rating.

2.1.14 Shoreside Boiler Demonstration of Fuel Water Emulsions

Particulate and oxides of nitrogen (NO_x) emissions were measured during a series of onshore tests of marine boilers.[24] The purpose of the tests were to determine the effect of different water-to-fuel emulsions on engine performance and subsequent emissions. To serve as a base reference in the test program, a series of tests were performed using oil with no water. These tests of 0% water in were considered appropriate for use in the emission factor data base.

Operational information and fuel characteristics were taken from ASME test forms presented in report document Appendix E. See Appendix D of this document for data summaries. Items included:

- Calculated total heat input (10^6 BTU/hr)
- Percent of load
- Fuel consumption (lb/hr) and density (specific gravity)

Emission rates were taken from Appendix H (of the source report), Summary Tables of Emission Test Results. Table values were presented in units of lb/10^6 BTU. Conversion of this value to lb/10^3 gal is achieved as follows:

Step 1 - (lb/10^6 BTU)(10^6 BTU/hr) = lb/hr emissions

Step 2 - (sp. gr.)(8.33 lb/gal water) = lb/gal fuel

Step 3 - $\frac{\text{lb/hr fuel}}{\text{1000 lb/gal fuel}}$ = 1000 gal/hr fuel

Step 4 - $\frac{\text{lb/hr emission}}{\text{1000 gal/hr fuel}}$ = lb emissions/1000 gal fuel

2.1.14.1 Test Methods

Tests were conducted using the following sampling procedures:
Particulate matter - EPA Methods 1 through 5
Oxides of Nitrogen - continuous monitoring using a Monitor Labs Model 8430 NO_x Chemiluminescent analyzer

2.1.14.2 Sample Calculations

Given: 13.15 x 10^6 BTU/hr heat input to boiler
711.4 lb/hr fuel rate
36.8% load
0.201 lb/10^6 BTU NO_x
0.9567 specific gravity

$$\text{Emissions} = 0.201 \text{ lb } NO_x/10^6 \text{ BTU} \times 13.15 \times 10^6 \text{ BTU/hr}$$
$$= 2.64 \text{ lb } NO_x \text{ hr}$$

$$\text{Fuel Density} = (0.9567)(8.33 \text{ lb/gal water}) = 7.97 \text{ lb/gal fuel}$$
$$\frac{711.4 \text{ lb/hr fuel}}{(1000)(7.97 \text{ lb/gal fuel})} = 0.089 \times 10^3 \text{ gal/hr fuel rate}$$

$$\frac{2.64 \text{ lb } NO_x/\text{hr}}{0.089 \times 10^3 \text{ gal/hr}} = \frac{29.6 \text{ lb } NO_x/10^3 \text{ gal}}$$

2.1.14.3 Data Source Rating

The Shoreside boiler tests were performed using EPA Referenced procedures as a guideline. However, a B rating was assigned because the reference did not contain enough field data to sufficiently document test results.

SECTION 3

DATA COMPILATION METHODOLOGY: PLEASURE CRAFT

Essentially two data sources were utilized to provide the emission data base for gasoline powered pleasure craft.[25,26] The data sources provide emission data for 2-stroke outboard motors.[a] The original diesel powered pleasure craft emission factors were not revised. Information used to develop the initial diesel factors were an extrapolation of Coast Guard data. With no additional information available on diesel combustion, these factors remain basically unchanged. Two changes were made in the format of the diesel pleasure craft emissions factors.[b] Using the original compilation, emission factors were presented by mode of operation. Also, VOC emission factors were developed for both methane and nonmethane emissions using chemical species data contained in Table 9-07-021 of Reference 3.

For gasoline powered pleasure craft, as in the case of steamships and motorships, data were converted to the same units (pounds per 1000 pounds fuel and grams per horsepower hour) for emission factor computation. Emission factors were presented in terms of percent load due to distinct trends in emissions as a function of engine load. A species breakdown of 7.6% methane, 92.4% nonmethane by weight (gasoline combustion in reciprocating engines) was assigned for VOC emission factor development. This was based on Table 9-06-021B from the document entitled Volatile Organic Compound (VOC) Species Data Manual, Second Edition, EPA-450/4-80-015.[3]

The following section provides a detailed discussion of the data sources and calculation methodology used to determine combustion emission factors for pleasure craft. Each data source was evaluated per the AP-42 emission factor preparation guidelines and assigned a rating.[27]

3.1 DATA SOURCES

3.1.1 Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines, Part 2 - Outboard Motors

Emission data for carbon monoxide, total hydrocarbons, and oxides of nitrogen used from this source were tests conducted on four outboard engines operated over a variety of horsepower ranges.[25] Conversion of mode values to horsepower settings for each test utilized reference document Table 2. Total

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[a]It is recommended that Section 3.2.5 of AP-42 entitled "Small General Utility Engines" be utilized in lieu of this section (3.2.3) for 4-stroke gasoline pleasure craft engines. The 4-stroke gasoline engines constitute the vast majority of inboard pleasure craft applications.

[b]Table 3.2.3-6 (Diesel Powered Inboard Pleasure Craft Emission Factors) from the main text Section 3.2.3.3 presents the unrevised composite emission factors in addition to the emission factors by % load originally used to develop the composite factors. These factors are based on 200 HP diesel engine Coast Guard vessel data. The user should refer to Table 3.2.3-4 (Emission Factors for Distillate and Diesel Fuel Fired Motorships) for inboard diesel powered pleasure craft powerplants well in excess of 200 HP.

mass emissions in g/hr were taken from Table 3 (both tables located in the referenced document). Horsepower settings were then converted to percent of load based on the rated engine size. These tables are presented in Appendix D.

As with the previous set, the emissions measured from the combustion of gasoline in the four engines were converted from g/hr to g/HP/hr by dividing the mass emission rate by the horsepower setting measured during the test. Fuel consumption figures were reported in the appropriate document appendix in lb/hr. Conversion to lb/10^3 gal based on fuel density of 6.17 lb/gal was achieved similarly to the previous data source discussion.

$$\text{Step 2 - } \frac{\text{lb/hr fuel}}{(6.17 \text{ lb/gal})(1000)} = 10^3 \text{ gal/hr fuel}$$

$$\frac{\text{lb/hr pollutant}}{10^3 \text{ gal/hr fuel}} = \text{lb pollutant}/10^3 \text{ gal fuel}$$

Emission testing of these outboard engines are consistent with testing procedures and instrumentation approved by EPA. It is difficult to trace the mass emission rates presented in the reference document for purposes of verification. Therefore, a B rating was assigned.

3.1.2 U.S. Coast Guard Pollution Abatement Program, Two Stroke Cycle Outboard Engine Emissions

Data were utilized from a study prepared by the Transportation Systems Center, Cambridge, MA.[26] Emissions were reported for total VOC oxides of nitrogen, and carbon monoxide. The total VOC were converted to mass quantities using the carbon balance technique. The procedure used was consistent with the equation presented in 40 CFR 86, Subpart D.

Emission values are reported in engine modes for each of the five engines tested. Translation from modes to engine performance was accomplished in Table 2, while emissions are taken taken from Table 7 (both located in the referenced document). Three measurements in grams per hour (g/hr) were reported for each test: (1) mass emissions, (2) emissions retained in water, (3) emissions vented to air. Results indicated a high variation in emissions scavaged in water due to engine design. Therefore, total mass emissions were utilized for the data base. Values were for outboard engines burning gasoline. It was assumed that inboard engines would be of similar size and design and exhibit similar emission characteristics.

The conversion of g/hr to grams per horsepower hour (g/HP/hr) was achieved by dividing the mass rate by the horsepower achieved during that particular test. Fuel consumption was provided for only one test series (1962 Mercury, 70 HP rated). Gram per hour emissions for this data set were converted to pounds per thousand gallons of fuel in the following 2 steps.

$$\text{Step 1 - } \frac{\text{g/hr}}{454 \text{ g/lb}} = \text{lb/hr}$$

$$\text{Step 2 - } \frac{\text{lb/hr}}{(\text{gal/hr})(1000)} = \text{lb}/10^3 \text{ gal}$$

Estimates for emission losses in water were obtained from Table 8 of the reference and are included in Appendix D. Losses in water as a percent of total mass emissions varied significantly. Averaged values over all modes ranged from 14.3 percent (carbon monoxide from the 1959 Johnson, rated at 50 HP) to 58 percent (total hydrocarbons from the 1964 Mercury, rated at 65 HP). While individual engine averages varied considerably, in general carbon monoxide losses in water were the lowest with total hydrocarbons the highest, and oxides of nitrogen ranging between the two.

Continuous analyzer testing consistent with EPA referenced methodology was performed on the outboard engines. Although the carbon balance technique used to calculate mass emissions was thoroughly discussed in the document, data traceability was difficult and thus a B rating was assigned.

3.2 EMISSION FACTOR CALCULATIONS

The data from the two sources indicated distinct trends in emissions based on percent of load. Therefore, it was decided that engine grouping would be based not on size, but on load condition. Data availability made the groupings somewhat different for g/HP/hr and lb/10^3 gal factors. Values are presented in the emission factor summary tables in Appendix C. Assembled values were averaged to arrive at final emission factors for each percent of load. Composite emission factors presented in Table 3.2.3-7 (GasolinePowered Inboard Pleasure Craft) of the main text were derived on a time weighted average basis using the following time in modes (or loads):[25]

1. In idle 12% of time;
2. Less than 10% full load 29% of time;
3. 10-50% full load 12% of time;
4. 50-90% full load 41% of time; and
5. 100% full load 6% of time.

SECTION 4

SUMMARY

4.1 EMISSION FACTOR EVALUATION

Each data source for steamships, motorships, and pleasure craft provided emission testing data using testing methodologies consistent with EPA methodology, however, complete data validation in most cases was not possible.

Distillate (diesel) powered motorship emission factors were grouped and compiled from A and B rated data in such a way as to minimize the population variability. Therefore, an overall rating of C was assigned to these factors. Residual powered motorship emission factors were developed from C rated data and may not represent a random sample from the industry. In this case, an overall rating of D was assigned.

Due to the small number of data sources (all A and B rated) used to compile the steamship emission factors, an overall rating of C was assigned.

Gasoline powered inboard pleasure craft emission factors were developed from B rated data covering a wider industry sampling than the previous AP-42 revision. In addition, distinct trends appeared within the load ranges selected for inboard pleasure craft emission factor compilation. However, the assumption that inboard and outboard engine emissions are similar is tenious, and an overall rating of D was thus assigned to these factors.

4.2 CONCLUSION

The revision to Section 3.2.3 of AP-42 provides emission factors based on an expanded data base more representative of the overall industry. Power plant size and load ranges selected for factor compilation along with vessel classification tables (Tables 3.2.3-1 and 3.2.3-2 of the main text) provide the user with a tool for effective emission factor application.

Table 3.2.3-4 (Residual Fuel Fired Motorship Emission Factors) of the main report is considered the most significant addition to this AP-42 section, in that it supplies the user with emission data on large diesel engines (>2680 KW, 3600 HP) not previously developed.

SECTION 5

REFERENCES

1. Air Pollution Engineering Manual, Second Edition, AP-42 U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1973. Out of Print.

2. Improved Marine Boiler Reliability Phase II, Volume IV: Stack Gas Analysis, Contract No. MA-6-38088, C-E Power Systems, Windsor, CT, February 1977.

3. Volatile Organic Compound (VOC) Species Data Manual, Second Edition. EPA-450/4-80-015, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1980. Out of Print.

4. M. G. Natrella, Experimental Statistics, NBS Handbook 91, National Bureau of Standards, U. S. Department of Commerce, Washington, DC, October 1966.

5. Compilation of Preliminary Particle Size Emission Factor Data Base, EPA-450/4-82-016, U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, November 1982.

6. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, April 1980.

7. Diesel engine combustion emission data for marine applications, Caterpiller Tractor Company, Peoria, IL, January 1983.

8. Diesel engine combustion emission data for marine applications, Colt Industries, Fairbanks-Morse Engine Division, Beloit, WI, February 1983.

9. W. C. Kelly, et al., Inventory of Emissions from Marine Operations within California Coastal Waters, Contract No. ARB-A6-208-30, Scott Environmental Technology, San Bernardino, CA, June 1981.

10. Marine diesel engine combustion emission data, American M. A. N. Corporation, San Francisco, CA, March 1983.

11. Diesel engine combustion emission data for marine applications, Cummins Engine Company, Inc., Columbus, IN, March 1983.

12. Diesel engine combustion emission data for marine diesel engines and generator sets, Detroit Diesel Allison Division of General Motors, Romulus, MI, March 1983.

13. A. F. Souza, A Study of Emissions from Coast Guard Cutters, Contract No. DOT-TSC-429, Scott Research Laboratories, Inc., Plumsteadville, PA, February 1973.

14. R. A. Walter, United States Coast Guard Pollution Abatement Program: Cutter Estimated Exhaust Emissions, Report No. DOT-TSC-USGC, U. S. Department of Transportation, Cambridge, MA, September 1975.

15. Consideration of Approval of a Draft Report to the Legislature on the Control of Visible Emissions from Ships with Steam Boilers, Acurex Corporation, Moutain View, CA, May 1982.

16. C. W. Coon, Multi-cylinder Diesel Engine Tests with Unstabilized Water Fuel Emulsion, Southwest Research Inc., San Antonio, TX, June 1981.

17. R. A. Walter, United States Coast Guard Pollution Abatement Program: A Preliminary Report on the Emissions Testing of Boat Diesel Engines, Report No. DOT-TSC-USCG-73-2, U. S. Department of Transportation, Cambridge, MA, November 1973.

18. Nitrogen Oxide Monitoring on an Oil Tanker, Scott Environmental Technology, Inc., Plumsteadville, PA, April 1977.

19. Overall review of Studies of Air Pollution from Naval Ship Propulsion Systems, USS L. Y. Spear Pollution Data, U. S. Department of the Navy, Bethesda, MD, April 1977.

20. Worldwide Analysis of Marine Bunker C Fuel Oils, Maritime Administration, U. S. Department of Transportation, Washington, DC, December 1980.

21. B. L. Wallace, Evaluation of Developed Methodology for Shipboard Steam Generator Systems, Report No. 28-463, U. S. Department of the Navy, Annapolis, MD, March 1973.

22. A. L. Waldron, Sampling of Emission Products from Ships' Boiler Stacks, Report No. 28-169, U. S. Department of the Navy, Annapolis, MD, April 1972.

23. B. L. Wallace, Pollution Monitoring of a 1200 PSI Shipboard Steam Generator, Report No. DTNSRDC/SME-81/15, U. S. Department of the Navy, Bethesda, MD, August 1981.

24. R. W. Cass, et al., Shoreside Boiler Demonstration of Fuel-Water Emulsions, Seaworthy Engine Systems, Inc., Essex, CT, August 1982.

25. C. T. Hare and K. J. Springer, Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines, Contract No. EHS 70-108, Southwest Research Institute, San Antonio, TX, October 1972 and January 1973.

26. U. S. Coast Guard Pollution Abatement Program, Two-stroke Cycle Outboard Engine Emissions, U. S. Department of Transportation Cambridge, MA, September 1975.

27. Draft 1979 Emissions Inventory, South Coast Air Basin, South Coast Air Quality Management District, El Monte, CA, July 1981.

28. Marine Engineering, Society of Naval Architects and Marine Engineers, New York, NY, 1973.

APPENDIX A

MOTORSHIP AND STEAMSHIP EXAMPLE STATISTICAL ANALYSIS

APPENDIX A

Sample Statistical Calculation for Motorships

Given: Diesel engines at 0-300 HP rated capacity and 0-15% load
There are 16 VOC data entries in $lb/10^3$ gal for this selection criteria
Avg. Value = 310.30 lb $VOC/10^3$ gal
Std. Dev. = 316.37 $lb/10^3$ gal
Confidence level selected was 90% (i.e., 10% risk of excluding valid THC data) and α is therefore equal to 0.10

$(1 - \alpha)^{1/n} = P$ (input to Table A-2)

where n = the number of data points

$(1 - 0.1)^{1/16} = 0.9934 = P$

In Table A-2 (Reference 27) Zp is the multiplier [K]

Using this table and interpolating, Zp (or K) = 2.50

The acceptability range is equal to the Avg. Value $\pm$ K Std. Dev. or 310.30 lb $VOC/10^3$ gal $\pm$ (2.50)(316.37 lb $VOC/10^3$ gal) = 310.3 $\pm$ 790.93 $lb/10^3$ gal for a range of 0 to 1101 lb $VOC/10^3$ gal

All data entries outside this range would be excluded prior to reaveraging. The data base had a VOC entry of 1312.2 $lb/10^3$ gal which was therefore excluded. The subsequent data population consisting of 15 data points was reaveraged which resulted in a VOC emission factor of 243.50 $lb/10^3$ gal.

The identical procedures were used for steamships.

APPENDIX B

MOTORSHIP AND STEAMSHIP DATA

Note:
1. Diesel or distillate fuel is represented on the computer printouts as ND or D, where ND = Navy Distillate fuel, and D = distillate fuel from other than naval sources. Residual or No. 6 fuel oil is represented by F06 or "neat" where "neat" refers to residual fuel with 0% water added during a water in fuel emulsion study.

2. -9.00 means there is no data entry in that position.

3. Load is in percent.

B-1. Steam Boiler/Generator Data for AP-42
Section Table 3.2.3-3

Methane-nonmethane fractions taken from
Reference 3, Table 1-01-004 for Residual Oil
and Reference 3, Table 1-01-004 for Distillate Oil

*** STEAM BOILERS ***
RESIDUAL OIL FIRED

RANGE 1=
MMBTU/HR 0.00- 400.00
LOAD 10.00- 60.00

RATED CAPACITY MMBTU/HR	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	LB POLLUTANT/MMBTU VOC	CO	NOX	PART	FUEL TYPE	REFERENCE #
36,00	31,40	-9,00	-9,00	26,70	7,37	-9,00	-9,00	0,18	0,05	NEAT	
36,00	39,80	-9,00	-9,00	22,80	4,02	-9,00	-9,00	0,16	0,03	NEAT	
36,00	39,80	-9,00	-9,00	22,10	7,05	-9,00	-9,00	0,15	0,05	NEAT	
36,00	31,40	-9,00	-9,00	25,60	7,56	-9,00	-9,00	0,17	0,05	NEAT	
36,00	40,40	-9,00	-9,00	23,00	4,89	-9,00	-9,00	0,16	0,03	NEAT	
36,00	32,80	-9,00	-9,00	22,70	11,50	-9,00	-9,00	0,15	0,08	NEAT	
36,00	40,40	-9,00	-9,00	21,80	19,30	-9,00	-9,00	0,15	0,13	NEAT	23
36,00	32,80	-9,00	-9,00	20,20	9,89	-9,00	-9,00	0,14	0,07	NEAT	
36,00	36,80	-9,00	-9,00	29,60	-9,00	-9,00	-9,00	0,20	-9,00	NEAT	
36,00	35,40	-9,00	-9,00	21,80	12,40	-9,00	-9,00	0,15	0,08	NEAT	
36,00	39,10	-9,00	-9,00	23,00	-9,00	-9,00	-9,00	0,16	-9,00	NEAT	
36,00	35,40	-9,00	-9,00	27,20	-9,00	-9,00	-9,00	0,19	-9,00	NEAT	
36,00	36,80	-9,00	-9,00	28,30	-9,00	-9,00	-9,00	0,19	-9,00	NEAT	
63,70	26,70	3,90	0,19	89,98	-9,00	0,03	0,00	0,60	-9,00	FO6	
138,40	49,60	-9,00	-9,00	39,30	-9,00	-9,00	-9,00	0,26	-9,00	FO6	
138,40	49,60	-9,00	-9,00	17,60	-9,00	-9,00	-9,00	0,12	-9,00	FO6	
138,40	34,00	-9,00	-9,00	15,20	-9,00	-9,00	-9,00	0,10	-9,00	FO6	17
138,40	30,60	-9,00	-9,00	13,10	-9,00	-9,00	-9,00	0,09	-9,00	FO6	
138,40	34,00	-9,00	-9,00	16,70	-9,00	-9,00	-9,00	0,11	-9,00	FO6	
138,40	34,00	-9,00	-9,00	10,70	-9,00	-9,00	-9,00	0,07	-9,00	FO6	
138,40	30,60	-9,00	-9,00	35,70	-9,00	-9,00	-9,00	0,24	-9,00	FO6	
148,00	29,00	-9,00	-9,00	35,65	-9,00	-9,00	-9,00	0,24	-9,00	FO6	
148,00	44,00	-9,00	-9,00	43,20	-9,00	-9,00	-9,00	0,29	-9,00	FO6	
148,00	44,00	-9,00	1,29	39,24	-9,00	-9,00	0,01	0,26	-9,00	FO6	
148,00	46,00	-9,00	-9,00	41,50	-9,00	-9,00	-9,00	0,28	-9,00	FO6	2
148,00	44,00	-9,00	1,94	39,24	-9,00	-9,00	0,01	0,26	-9,00	FO6	
148,00	29,00	-9,00	-9,00	35,30	-9,00	-9,00	-9,00	0,24	-9,00	FO6	
148,00	27,00	-9,00	-9,00	40,40	-9,00	-9,00	-9,00	0,27	-9,00	FO6	
148,00	46,00	-9,00	0,96	42,62	-9,00	-9,00	0,01	0,29	-9,00	FO6	
148,00	46,00	-9,00	0,27	41,72	-9,00	-9,00	0,00	0,28	-9,00	FO6	
148,00	29,00	-9,00	-9,00	35,30	-9,00	-9,00	-9,00	0,24	-9,00	FO6	
148,00	27,00	-9,00	-9,00	40,40	-9,00	-9,00	-9,00	0,27	-9,00	FO6	
148,00	11,00	-9,00	0,77	40,40	-9,00	-9,00	0,01	0,27	-9,00	FO6	
163,83	28,90	1,93	-9,00	15,05	-9,00	0,01	-9,00	0,10	-9,00	FO6	
163,83	41,70	0,24	9,12	44,62	-9,00	0,00	0,06	0,30	-9,00	FO6	
163,83	54,80	2,25	76,78	58,50	-9,00	0,02	0,51	0,39	-9,00	FO6	9
163,83	59,90	0,35	15,37	59,90	-9,00	0,00	0,10	0,40	-9,00	FO6	
163,83	48,60	0,26	0,75	44,90	-9,00	0,00	0,01	0,30	-9,00	FO6	
163,83	26,70	0,42	0,19	90,00	-9,00	0,00	0,00	0,60	-9,00	FO6	
249,00	11,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	FO6	
249,00	35,00	-9,00	-9,00	78,80	-9,00	-9,00	-9,00	0,52	-9,00	FO6	
249,00	10,00	-9,00	-9,00	59,10	-9,00	-9,00	-9,00	0,39	-9,00	FO6	20
249,00	10,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	FO6	
249,00	10,00	-9,00	-9,00	38,60	-9,00	-9,00	-9,00	0,26	-9,00	FO6	
257,00	35,00	-9,00	-9,00	-9,00	44,30	-9,00	-9,00	-9,00	0,29	FO6	
341,80	48,60	2,39	0,75	44,87	-9,00	0,02	0,00	0,30	-9,00	FO6	9
AVG 132,68	34,86	1,47 ‡	9,03	36,33	12,83	0,00984 ‡ 0,01	0,060* 0,06	0,24	0,084* 0,09		
	g/l		1,1	43	1,5	g/10⁶J	0,026	0,10	0,037		
STD 75,47	11,52	1,27	20,90	18,31	11,29	0,01	0,14	0,12	0,07		
		8	12	43	10	8	13	43	10		

* CONVERTERED FROM FUEL USE UNITS ASSUMING 150,000 BTU/GAL

‡ FROM REF. 3, T 1-01-004

	CH4	NMVOC
LB/10³ GAL	0.16	1.3
g/l	0.019	0.15
LB/10⁶ BTU	0.0011	0.0087
g/10⁶J	0.0005	0.0037

LOAD 75,00- 115,00

RATED CAPACITY MMBTU/HR	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	LB POLLUTANT/MMBTU VOC	CO	NOX	PART	FUEL TYPE	
36,00	108,10	-9,00	-9,00	30,30	7,20	-9,00	-9,00	0,21	0,05	NEAT	
36,00	95,60	-9,00	-9,00	35,60	20,00	-9,00	-9,00	0,24	0,14	NEAT	
36,00	97,80	-9,00	-9,00	30,60	16,20	-9,00	-9,00	0,21	0,11	NEAT	
36,00	95,60	-9,00	-9,00	34,20	17,70	-9,00	-9,00	0,23	0,12	NEAT	
36,00	99,40	-9,00	-9,00	29,00	7,01	-9,00	-9,00	0,20	0,05	NEAT	
36,00	94,80	-9,00	-9,00	28,00	-9,00	-9,00	-9,00	0,19	-9,00	NEAT	
36,00	110,90	-9,00	-9,00	34,30	10,20	-9,00	-9,00	0,23	0,07	NEAT	23
36,00	108,10	-9,00	-9,00	29,90	6,33	-9,00	-9,00	0,20	0,04	NEAT	
36,00	110,90	-9,00	-9,00	34,30	9,22	-9,00	-9,00	0,23	0,06	NEAT	
36,00	97,80	-9,00	-9,00	27,00	14,90	-9,00	-9,00	0,18	0,10	NEAT	
36,00	94,80	-9,00	-9,00	35,10	20,50	-9,00	-9,00	0,24	0,14	NEAT	
36,00	99,40	-9,00	-9,00	28,00	6,98	-9,00	-9,00	0,19	0,05	NEAT	
138,40	83,30	-9,00	-9,00	57,60	-9,00	-9,00	-9,00	0,39	-9,00	FO6	
138,40	100,90	-9,00	-9,00	75,00	-9,00	-9,00	-9,00	0,50	-9,00	FO6	
138,40	85,00	-9,00	-9,00	37,90	-9,00	-9,00	-9,00	0,25	-9,00	FO6	
138,40	86,00	-9,00	-9,00	56,40	-9,00	-9,00	-9,00	0,38	-9,00	FO6	
138,40	89,00	-9,00	-9,00	51,20	-9,00	-9,00	-9,00	0,34	-9,00	FO6	
138,40	87,40	-9,00	-9,00	50,50	-9,00	-9,00	-9,00	0,34	-9,00	FO6	
138,40	100,20	-9,00	-9,00	60,70	-9,00	-9,00	-9,00	0,41	-9,00	FO6	
138,40	83,30	-9,00	-9,00	58,30	-9,00	-9,00	-9,00	0,39	-9,00	FO6	
138,40	100,20	-9,00	-9,00	47,90	-9,00	-9,00	-9,00	0,32	-9,00	FO6	
138,40	84,30	-9,00	-9,00	50,50	-9,00	-9,00	-9,00	0,34	-9,00	FO6	17
138,40	99,40	-9,00	-9,00	61,00	-9,00	-9,00	-9,00	0,41	-9,00	FO6	
138,40	86,40	-9,00	-9,00	59,50	-9,00	-9,00	-9,00	0,40	-9,00	FO6	
138,40	85,00	-9,00	-9,00	17,40	-9,00	-9,00	-9,00	0,12	-9,00	FO6	
138,40	99,40	-9,00	-9,00	63,80	-9,00	-9,00	-9,00	0,43	-9,00	FO6	
138,40	100,20	-9,00	-9,00	14,50	-9,00	-9,00	-9,00	0,10	-9,00	FO6	
138,40	89,00	-9,00	-9,00	49,80	-9,00	-9,00	-9,00	0,33	-9,00	FO6	
138,40	86,00	-9,00	-9,00	46,70	-9,00	-9,00	-9,00	0,31	-9,00	FO6	
138,40	87,40	-9,00	-9,00	58,80	-9,00	-9,00	-9,00	0,39	-9,00	FO6	
138,40	84,30	-9,00	-9,00	52,40	-9,00	-9,00	-9,00	0,35	-9,00	FO6	
138,40	98,00	-9,00	-9,00	37,90	-9,00	-9,00	-9,00	0,25	-9,00	FO6	
138,40	86,40	-9,00	-9,00	70,00	-9,00	-9,00	-9,00	0,47	-9,00	FO6	
138,40	100,90	-9,00	-9,00	76,40	-9,00	-9,00	-9,00	0,51	-9,00	FO6	
138,40	83,30	-9,00	-9,00	34,80	-9,00	-9,00	-9,00	0,23	-9,00	FO6	
138,40	100,90	-9,00	-9,00	71,70	-9,00	-9,00	-9,00	0,48	-9,00	FO6	
138,40	86,00	-9,00	-9,00	34,30	-9,00	-9,00	-9,00	0,23	-9,00	FO6	
138,40	100,90	-9,00	-9,00	79,30	-9,00	-9,00	-9,00	0,53	-9,00	FO6	
138,40	98,00	-9,00	-9,00	-9,00	43,60	-9,00	-9,00	-9,00	0,29	FO6	
138,40	83,30	-9,00	-9,00	30,50	-9,00	-9,00	-9,00	0,20	-9,00	FO6	
148,00	111,00	-9,00	-9,00	41,97	-9,00	-9,00	1,60	0,28	-9,00	FO6	
148,00	109,00	-9,00	0,65	59,21	-9,00	-9,00	0,00	0,40	-9,00	FO6	
148,00	95,00	-9,00	40,74	44,51	-9,00	-9,00	0,27	0,30	-9,00	FO6	
148,00	94,00	-9,00	1,92	52,09	-9,00	-9,00	0,01	0,35	-9,00	FO6	
148,00	109,00	-9,00	0,65	59,21	-9,00	-9,00	0,00	0,40	-9,00	FO6	
148,00	95,00	-9,00	36,80	44,51	-9,00	-9,00	0,25	0,30	-9,00	FO6	
148,00	111,00	-9,00	-9,00	41,97	-9,00	-9,00	1,60	0,28	-9,00	FO6	
148,00	95,00	-9,00	40,74	44,51	-9,00	-9,00	0,27	0,30	-9,00	FO6	
148,00	94,00	-9,00	1,92	52,09	-9,00	-9,00	0,01	0,35	-9,00	FO6	
148,00	79,00	-9,00	17,04	39,44	-9,00	-9,00	0,11	0,26	-9,00	FO6	
148,00	111,00	-9,00	219,84	41,97	-9,00	-9,00	1,60	0,28	-9,00	FO6	
148,00	79,00	-9,00	4,87	39,44	-9,00	-9,00	0,03	0,26	-9,00	FO6	
148,00	79,00	-9,00	-9,00	39,44	-9,00	-9,00	-0,05	0,26	-9,00	FO6	
148,00	78,00	-9,00	-9,00	45,07	-9,00	-9,00	-9,00	0,31	-9,00	FO6	
148,00	110,00	-9,00	1,21	52,60	-9,00	-9,00	0,01	0,35	-9,00	FO6	
148,00	94,00	-9,00	-9,00	59,19	-9,00	-9,00	-9,00	0,40	-9,00	FO6	
148,00	109,00	-9,00	0,65	59,21	-9,00	-9,00	0,00	0,40	-9,00	FO6	
148,00	95,00	-9,00	36,80	44,51	-9,00	-9,00	0,25	0,30	-9,00	FO6	
148,00	95,00	-9,00	36,80	44,51	-9,00	-9,00	0,25	0,30	-9,00	FO6	
148,00	78,00	-9,00	-9,00	45,07	-9,00	-9,00	-9,00	0,31	-9,00	FO6	
148,00	94,00	-9,00	1,92	52,09	-9,00	-9,00	0,01	0,35	-9,00	FO6	
148,00	110,00	-9,00	4,83	52,60	-9,00	-9,00	0,03	0,35	-9,00	FO6	
148,00	94,00	-9,00	-9,00	59,19	-9,00	-9,00	-9,00	0,40	-9,00	FO6	
148,00	95,00	-9,00	40,74	44,51	-9,00	-9,00	0,27	0,30	-9,00	FO6	
148,00	94,00	-9,00	-9,00	59,19	-9,00	-9,00	-9,00	0,40	-9,00	FO6	
148,00	78,00	-9,00	-9,00	45,07	-9,00	-9,00	-9,00	0,31	-9,00	FO6	
148,00	110,00	-9,00	4,83	52,60	-9,00	-9,00	0,03	0,35	-9,00	FO6	
148,00	94,00	-9,00	1,92	52,09	-9,00	-9,00	0,01	0,35	-9,00	FO6	
163,83	89,60	9,58	9,61	60,37	-9,00	0,06	0,06	0,41	-9,00	FO6	
163,83	100,00	0,11	46,05	58,07	-9,00	0,00	0,31	0,39	-9,00	FO6	
163,83	91,50	0,26	10,29	56,92	-9,00	0,00	0,69	0,38	-9,00	FO6	
163,83	105,80	0,07	37,90	60,50	-9,00	0,00	0,25	0,41	-9,00	FO6	9
163,83	102,60	0,14	21,46	62,70	-9,00	0,00	0,14	0,42	-9,00	FO6	
249,00	100,00	-9,00	-9,00	92,40	-9,00	-9,00	-9,00	0,61	-9,00	FO6	
249,00	100,00	-9,00	-9,00	95,40	-9,00	-9,00	-9,00	0,63	-9,00	FO6	20
257,00	100,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	FO6	20
AVG	131,91	95,34	2,03	= 25,84	49,13	14,99	0,01	0,30	0,33	0,10	
		g/L		3,1	5,9	1,8 g/10⁶J		= 0,13	0,14	0,043	
STD	46,87	9,40	3,77	43,75	15,25	10,01	0,02	0,48	0,10	0,07	
n=			5	24	74	12	5	7	74	12	

2014*

* CONVERTED FROM FUEL USE BASED EMISSION FACTOR ASSUMING 150,000 BTU/GAL OIL.

	CH4	NMVOC	
#lb/10³gal	0.22	1.8	FROM REF 3, T. 1-01-004
g/L	0.026	0.22	
lb/10⁶BTU	0.005	0.012	
g/10⁶J	0.0006	0.0052	

*** STEAM BOILERS ***
DISTILLATE OIL FIRED

RANGE :=
MMBTU/HR - 0.00= 400.00
LOAD 11.00= 11.00

	RATED CAPACITY MMBTU/HR	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	LB POLLUTANT/MMBTU VOC	CO	NOX	PART	FUEL TYPE	REFERENCE #
	257,00	11,00	-9,00	-9,00	-9,00	16,40	-9,00	-9,00	-9,00	0,12	ND	20
	257,00	11,00	-9,00	-9,00	24,70	-9,00	-9,00	-9,00	0,18	-9,00	ND	
	257,00	11,00	-9,00	-9,00	-9,00	158,30	-9,00	-9,00	-9,00	1,15	ND	
	257,00	11,00	-9,00	-9,00	-9,00	273,90	-9,00	-9,00	-9,00	1,99	ND	
	257,00	11,00	-9,00	-9,00	22,00	-9,00	-9,00	-9,00	0,16	-9,00	ND	
	257,00	11,00	-9,00	-9,00	-9,00	71,10	-9,00	-9,00	-9,00	0,52	ND	
	257,00	11,00	-9,00	-9,00	20,60	-9,00	-9,00	-9,00	0,15	-9,00	ND	
	257,00	11,00	-9,00	-9,00	22,00	-9,00	-9,00	-9,00	0,16	-9,00	ND	
						exclude				exclude		
AVG	257,00	11,00	-9,00	-9,00	22,33	129,93	-9,00	-9,00	0,16	0,94		
			—	—	2,7	15,6	—	—	0,069	0,40		
STD	0,00	0,00	-9,00	-9,00	1,49	97,32	-9,00	-9,00	0,01	0,71		
h=			0	0	4	4	0	0	4	4		

g/L g/10⁶J

*** STEAM BOILERS ***
DISTILLATE OIL FIRED

RANGE :=
MMBTU/HR 0.00= 400.00
LOAD 20,00= 30.00

	RATED CAPACITY MMBTU/HR	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	LB POLLUTANT/MMBTU VOC	CO	NOX	PART	FUEL TYPE	REFERENCE #
	139,40	20,00	-9,00	-9,00	-9,00	8,98	-9,00	-9,00	-9,00	0,07	ND	21
	145,70	27,00	-9,00	15,30	8,40	9,08	-9,00	0,11	0,06	0,06	ND	18
	145,70	27,00	-9,00	-9,00	12,60	6,98	-9,00	-9,00	0,09	0,05	ND	18
	197,66	20,00	2,07	5,56	34,70	5,00	0,01	0,04	0,25	0,04	ND	22
	197,66	20,00	1,45	4,17	34,70	3,89	0,01	0,03	0,25	0,03	ND	
	197,66	26,00	0,62	0,62	29,20	5,42	-9,00	0,00	0,21	0,04	ND	
	197,66	20,00	1,03	16,70	33,30	2,22	0,01	0,12	0,24	0,02	ND	
	197,66	26,00	1,03	2,78	32,00	5,56	0,01	0,02	0,23	0,04	ND	
				6,95 F			[0,0089 *	0,050*				
AVG	177,39	23,25	1,24	7,52	26,41	5,89	0,01	0,05	0,19	0,042*		
			g/l → 0,15	0,83	32	0,71	g/10⁶J 0,0038	0,022	0,082	0,018		
STD	26,23	3,27	0,49	6,19	10,27	2,22	0,00	0,05	0,07	0,01		
h=			5	6	7	8	4	6	7	8		

From T. 1-01-005 Ref. 3
(100% non-methane VOC)

* CONVERTED FROM FUEL USE [redacted] UNITS ASSUMING 140,000 BTU/GAL.

F Averaged with 35-60% load

*** STEAM BOILERS ***
DISTILLATE OIL FIRED

RANGE 1=
MMBTU/HR 0,00= 400,00
LOAD 35,00= 60,00

	RATED CAPACITY MMBTU/HR	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	LB POLLUTANT/MMBTU VOC	CO	NOX	PART	FUEL TYPE	REFERENCE #
	110,00	50,00	-9,00	-9,00	-9,00	51,40	-9,00	-9,00	-9,00	0,37	ND	21
	139,40	40,00	-9,00	-9,00	-9,00	6,73	-9,00	-9,00	-9,00	0,05	ND	21
	145,70	57,00	-9,00	3,53	3,50	4,89	-9,00	0,03	0,25	0,04	ND	18
	257,00	35,00	-9,00	-9,00	22,00	-9,00	-9,00	-9,00	0,16	-9,00	ND	20
	257,00	35,00	-9,00	-9,00	21,30	-9,00	-9,00	-9,00	0,16	-9,00	ND	
	257,00	35,00	-9,00	-9,00	-9,00	18,90	-9,00	-9,00	-9,00	0,14	ND	
	257,00	35,00	-9,00	-9,00	28,90	-9,00	-9,00	-9,00	0,21	-9,00	ND	
	257,00	35,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	-9,00	ND	
	257,00	35,00	-9,00	-9,00	26,10	-9,00	-9,00	-9,00	0,19	-9,00	ND	
				6,95				0,057				
AVG	215,23	39,67	-9,00	3,53	20,36	20,48	-9,00	0,03	0,19	0,15		
			— 3/2	≠	2.9	25	— 2/10⁶J	≠	0,082	0,065		
STD	59,75	7,73	-9,00	0,00	8,87	18,65	-9,00	0,00	0,03	0,13		
n=			0	1	5	4	0	1	5	4		

≠ n<4, THEREFORE CO DATA AVERAGED WITH 20-30% LOAD RANGE DATA

*** STEAM BOILERS ***
DISTILLATE OIL FIRED

RANGE 1=
MMBTU/HR 0,00= 400,00
LOAD 95,00= 100,00

	RATED CAPACITY MMBTU/HR	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	LB POLLUTANT/MMBTU VOC	CO	NOX	PART	FUEL TYPE	REFERENCE #
	110,00	100,00	-9,00	-9,00	-9,00	14,60	-9,00	-9,00	-9,00	-9,00	ND	21
	139,40	95,00	-9,00	-9,00	-9,00	3,99	-9,00	-9,00	-9,00	0,03	ND	21
	145,70	100,00	-9,00	-9,00	-9,00	4,75	-9,00	-9,00	0,20	0,03	ND	18
	257,00	100,00	-9,00	-9,00	39,90	-9,00	-9,00	-9,00	0,29	-9,00	ND	20
	257,00	100,00	-9,00	-9,00	44,00	-9,00	-9,00	-9,00	0,32	-9,00	ND	
	257,00	100,00	-9,00	-9,00	49,50	-9,00	-9,00	-9,00	0,36	-9,00	ND	
	257,00	100,00	-9,00	-9,00	27,50	-9,00	-9,00	-9,00	0,20	-9,00	ND	
	257,00	100,00	-9,00	-9,00	41,20	-9,00	-9,00	-9,00	0,30	-9,00	ND	
	257,00	100,00	-9,00	-9,00	-9,00	63,70	-9,00	-9,00	-9,00	0,46	ND	
	257,00	100,00	-9,00	-9,00	-9,00	109,60	-9,00	-9,00	-9,00	0,80	ND	
	257,00	100,00	-9,00	-9,00	-9,00	10,00	-9,00	-9,00	-9,00	0,07	ND	
	257,00	100,00	-9,00	-9,00	42,60	-9,00	-9,00	-9,00	0,31	-9,00	ND	
AVG	225,68	99,58	-9,00	-9,00	40,78	34,44	-9,00	-9,00	0,28	0,28		
			—	— 3/2	4.9	4.1	8/10⁶J —	—	0.12	0.12		
STD	54,81	1,38	-9,00	-9,00	6,67	39,38	-9,00	-9,00	0,06	0,31		
n=			0	0	6	6	0	0	7	5		

B-2. Diesel Engine Data for AP-42 Section Table 3.2.3-4

Methane-nonmethane fractions taken from Reference 3, Table 2-01-003 for Diesel or Distillate Oil and Reference 3, Table 2-02-001 for Residual Oil

RANGES :-

HP	0.00-	299.90
LOAD	0.00-	14.90

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE	Reference #
			VOC	CO	NOX	PART	VOC	CO	NOX	PART		
	26.80	0.00	240.90	235.60	447.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	26.80	0.00	169.50	103.20	634.90	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	26.80	0.00	294.50	120.50	310.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	26.80	0.00	268.40	201.10	549.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	26.80	0.00	62.40	97.30	375.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	53.60	0.00	484.60	162.20	238.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	53.60	0.00	668.20	129.30	183.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	69.70	0.00	-9.00	492.20	245.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	200.00	0.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	D	17
	200.00	1.50	383.90	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	1.50	426.10	54.90	6.90	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	200.00	11.00	-9.00	-9.00	-9.00	-9.00	22.80	17.30	21.20	-9.00	D	17
	200.00	1.50	363.70	71.70	5.90	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	11.00	-9.00	-9.00	-9.00	-9.00	23.20	16.90	20.50	-9.00	D	
	200.00	9.00	-9.00	-9.00	-9.00	-9.00	11.00	22.60	15.80	-9.00	D	16
	200.00	10.00	-9.00	-9.00	-9.00	-9.00	7.40	38.50	33.50	-9.00	D	
	200.00	10.00	-9.00	-9.00	-9.00	-9.00	10.80	22.00	14.40	-9.00	D	
	225.00	2.00	131.40	232.00	123.50	-9.00	40.00	-9.00	37.60	-9.00	D2	11
	268.20	0.00	32.20	122.70	139.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	268.20	0.00	6.12	86.60	167.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	268.20	0.00	96.30	189.70	122.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	269.00	8.00	-9.00	204.50	365.00	-9.00	-9.00	7.60	13.90	-9.00	D	12
	290.00	2.00	24.40	119.80	150.40	-9.00	5.02	24.60	30.90	-9.00	D2	11
AVG	160.85	2.93	243.50	163.96	254.19	-9.00	17.17	21.41	23.47	-9.00		
STD	93.72	4.19	188.10	100.77	175.68	-9.00	11.41	8.76	8.68	-9.00		
		N/M-VOC	215.259				15.180					
		M-VOC	28.246				1.990					
							23.025	28.711	31.473			(g/kw-HR = X1.341)
(g/l = Y.1198)			29.171	19.642	30.452							
		N/MVOC	25.787				MVOC	2.671				
		MVOC	3.384				N/MVOC	20.354				
							37.860	47.209	51.751			(lb/10^3 HP-HR = X2.205)
							MVOC	4.312				
							N/MVOC	33.468				

RANGE :-
HP 0.00- 299.90
LOAD 15.00- 45.00

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE	Ref #
			VOC	CO	NOX	PART	VOC	CO	NOX	PART		
	25.80	30.00	93.30	41.70	-9.00	-9.00	33.80	-9.00	12.60	-9.00	ND	
	26.80	30.00	56.10	42.60	466.30	-9.00	28.20	16.90	21.40	-9.00	ND	
	26.80	40.00	382.70	73.80	325.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	26.80	35.00	357.30	77.00	342.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	69.70	35.00	864.00	237.80	332.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	69.70	20.00	-9.00	129.00	214.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	69.70	35.00	887.50	227.60	311.90	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	69.70	45.00	-9.00	94.70	717.60	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	69.70	45.00	760.70	194.50	322.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	84.50	20.00	106.30	145.20	160.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	84.50	20.00	180.80	175.70	73.90	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	107.30	25.00	523.50	98.90	243.40	-9.00	29.60	5.50	13.70	-9.00	ND	
	107.30	25.00	511.30	97.90	278.70	-9.00	23.20	4.40	12.70	-9.00	ND	
	107.30	25.00	429.10	58.20	240.80	-9.00	23.10	3.19	13.00	-9.00	ND	
	107.30	25.00	525.30	99.60	229.00	-9.00	34.07	6.52	14.70	-9.00	ND	
	107.30	25.00	486.60	104.40	273.80	-9.00	22.00	4.74	12.40	-9.00	ND	
	107.30	25.00	423.10	56.00	228.40	-9.00	22.70	3.61	12.20	-9.00	ND	
	200.00	36.00	-9.00	-9.00	-9.00	-9.00	3.20	3.50	11.20	-9.00	D	17
	200.00	34.00	-9.00	-9.00	-9.00	-9.00	13.50	4.20	16.30	-9.00	D	17
	200.00	30.10	123.00	111.10	130.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	30.10	115.70	205.10	372.20	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	34.00	-9.00	-9.00	-9.00	-9.00	11.30	3.90	14.70	-9.00	D	17
	200.00	30.10	147.10	282.90	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	35.00	-9.00	-9.00	-9.00	-9.00	4.30	3.70	11.20	-9.00	D	17
	200.00	36.00	-9.00	-9.00	-9.00	-9.00	13.10	3.50	15.30	-9.00	D	17
	200.00	30.10	55.70	84.70	71.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	34.00	-9.00	-9.00	-9.00	-9.00	6.80	4.90	15.80	-9.00	D	17
	225.00	25.00	25.40	98.70	135.00	-9.00	1.05	4.08	5.58	-9.00	D2	11
	268.20	30.00	14.70	56.90	155.20	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	268.20	40.00	13.00	28.70	163.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	269.00	25.00	-9.00	77.50	366.70	-9.00	-9.00	2.42	11.40	-9.00	D	12
	290.00	25.00	12.40	38.40	166.70	-9.00	0.43	1.33	5.77	-9.00	D2	11
AVG	143.40	30.61	308.50	113.02	242.61	-9.00	16.90	4.70	12.94	-9.00		
STD	79.73	6.57	273.43	66.84	98.05	-9.00	11.28	3.35	3.58	-9.00		

MVOC 35.786
N/MVOC 272.714
(g/l = X.1198) 36.958 13.540 29.665 22.443 6.393 17.353 (g/kw-HR = X1.341)
MVOC 4.287
N/MVOC 32.671
MVOC 2.629
N/MVOC 20.034
37.245 10.314 28.533 (lb/10^3 HP-HR = X1.341)
MVOC 4.323
N/MVOC 32.942

RANGE :-
HP 0.00- 299.90
LOAD 50.00- 74.90

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE	R.F #
			VOC	CO	NOX	PART	VOC	CO	NOX	PART		
	26.80	50.00	257.80	42.60	391.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	26.80	50.00	384.20	64.60	390.90	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	26.80	60.00	222.60	58.50	426.20	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	26.80	70.00	47.70	30.90	549.00	-9.00	-9.00	-9.00	16.20	-9.00	ND	13
	53.60	50.00	272.90	69.20	236.60	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	53.60	50.00	303.30	68.60	211.30	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	53.60	50.00	284.00	71.00	228.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	200.00	71.00	-9.00	-9.00	-9.00	-9.00	4.20	6.50	14.10	-9.00	D	17
	200.00	55.00	-9.00	-9.00	-9.00	-9.00	7.40	2.40	14.60	-9.00	D	
	200.00	51.00	-9.00	-9.00	-9.00	-9.00	2.70	2.70	11.80	-9.00	D	
	200.00	67.50	211.80	121.70	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	68.00	-9.00	-9.00	-9.00	-9.00	5.30	2.60	13.20	-9.00	D	17
	200.00	67.50	113.90	129.40	422.90	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	54.00	-9.00	-9.00	-9.00	-9.00	4.30	2.70	13.30	-9.00	D	
	200.00	52.00	-9.00	-9.00	-9.00	-9.00	2.80	2.60	10.50	-9.00	D	
	200.00	54.00	-9.00	-9.00	-9.00	-9.00	7.30	2.40	15.20	-9.00	D	17
	200.00	71.00	-9.00	-9.00	-9.00	-9.00	4.10	6.10	13.70	-9.00	D	
	200.00	54.00	-9.00	-9.00	-9.00	-9.00	5.40	2.70	13.10	-9.00	D	
	200.00	70.00	-9.00	-9.00	-9.00	-9.00	5.70	3.00	12.20	-9.00	D	
	200.00	67.50	143.60	132.70	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	225.00	50.00	13.10	77.40	195.50	-9.00	0.40	2.36	5.96	-9.00	D2	11
	268.20	73.00	29.40	70.10	143.30	-9.00	0.77	1.80	3.69	-9.00	ND	
	268.20	63.00	20.70	97.90	117.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	268.20	55.00	14.80	43.60	117.20	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	269.00	50.00	-9.00	41.90	463.50	-9.00	-9.00	1.10	12.10	-9.00	D	12
	290.00	50.00	7.98	33.00	276.70	-9.00	0.22	0.91	7.63	-9.00	D2	11
AVG	171.41	54.60	155.19	72.07	297.95	-9.00	3.89	2.98	11.82	-9.00		
STD	85.59	8.56	124.36	31.82	135.22	-9.00	2.32	1.58	3.39	-9.00		

MVOC 18.002
N/MVOC 137.188

(g/l = X.1198)

	18.572	9.634	35.694		5.216	3.862	15.851	(g/kw-hr = X1.341)
MVOC	2.157			MVOC	0.605			
N/MVOC	16.435			N/MVOC	4.611			
					8.577	6.350	26.063	(lb/10³HP-HR = X2.205)
				MVOC	0.995			
				N/MVOC	7.582			

RANGE :-
HP 0.00- 299.90
LOAD 75.00- 100.00

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE	Ref #
			VOC	CO	NOX	PART	VOC	CO	NOX	PART		
	26.80	80.00	34.40	18.90	469.70	-9.00	-9.00	5.97	14.10	-9.00	ND	
	53.60	75.00	206.20	59.60	251.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	53.60	75.00	258.10	69.80	216.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	53.60	75.00	242.40	72.90	235.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	80.50	99.00	163.00	278.70	77.70	-9.00	4.12	6.99	1.97	-9.00	ND	
	85.00	100.00	3.90	43.10	149.00	3.92	0.10	1.20	4.10	0.12	D2	7
	100.00	100.00	3.20	35.50	133.90	3.23	0.10	1.90	3.80	0.10	D2	
	175.00	100.00	3.90	41.60	184.40	6.49	0.10	1.20	5.20	0.17	D2	
	140.00	100.00	3.60	45.80	216.90	7.73	0.10	1.20	5.80	0.20	D2	
	165.00	100.00	2.90	42.30	201.00	9.62	0.10	1.20	5.80	0.27	D2	
	200.00	91.00	-9.00	-9.00	-9.00	-9.00	1.20	9.30	11.70	-9.00	D	17
	200.00	76.00	-9.00	-9.00	-9.00	-9.00	1.70	7.70	11.00	-9.00	D	17
	200.00	79.00	21.90	93.50	109.30	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	200.00	79.00	15.00	349.10	214.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	79.00	23.50	77.10	199.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	200.00	79.00	114.00	59.30	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	200.00	75.00	-9.00	-9.00	-9.00	-9.00	1.10	6.50	10.70	-9.00	D	
	200.00	93.00	-9.00	-9.00	-9.00	-9.00	5.10	8.70	12.80	-9.00	D	17
	200.00	93.00	-9.00	-9.00	-9.00	-9.00	4.10	11.20	13.50	-9.00	D	
	200.00	79.00	95.70	69.40	426.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	200.00	79.00	133.10	73.10	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	210.00	100.00	1.70	211.30	262.60	-9.00	0.05	5.20	6.50	-9.00	D2	7
	225.00	75.00	9.01	66.50	266.70	-9.00	0.24	1.77	7.10	-9.00	D2	11
	225.00	100.00	6.47	66.60	324.00	-9.00	0.17	1.75	8.51	-9.00	D2	11
	250.00	100.00	2.20	13.10	241.60	5.11	0.10	0.32	6.00	0.12	D2	7
	268.20	85.00	2.63	16.70	138.60	-9.00	0.12	0.76	6.27	-9.00	ND	13
	269.00	100.00	-9.00	-9.00	522.80	-9.00	-9.00	9.60	12.80	-9.00	D	12
	269.00	75.00	-9.00	67.60	570.00	-9.00	-9.00	1.68	14.10	-9.00	D	12
	270.00	100.00	2.60	26.90	170.50	2.56	0.10	0.70	4.50	0.06	D2	7
	290.00	100.00	5.64	39.90	463.50	-9.00	0.14	0.99	11.50	-9.00	D2	11
	290.00	75.00	5.47	28.50	371.70	-9.00	0.14	0.73	9.51	-9.00	D2	11
AVG	182.24	87.61	56.69	78.67	267.45	5.45	0.99	3.92	8.51	0.15		
STD	74.40	10.84	81.63	79.41	132.32	2.31	1.57	3.58	3.69	0.07		
			MVOC 6.576									
			N/MVOC 50.114									
(g/l = X.1198)			6.791	9.425	32.041	0.653	1.328	5.257	11.912	0.201		(g/KW-HR = X 1.341)
			MVOC 0.788			MVOC	0.154					
			N/MVOC 6.003			N/MVOC	1.174					
							2.183	8.644	18.765	0.331		(lb/10**3 HP-HR = X 2.205)
						MVOC	0.253					
						N/MVOC	1.930					

RANGE 1-
HP 300.00- 900.00
LOAD 0.00- 10.00

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/1000 GAL				G/HP-HR				FUEL TYPE	Ref #
			VOC	CO	NOX	PART	VOC	CO	NOX	PART		
	310.00	10.00	-9.00	144.40	336.70	-9.00	-9.00	6.16	14.40	-9.00	D	
	310.00	2.00	-9.00	319.90	236.70	-9.00	-9.00	17.60	13.00	-9.00	D	12
	340.00	2.00	-9.00	239.20	330.30	-9.00	-9.00	26.90	37.10	-9.00	D	
	340.00	2.00	109.30	139.90	45.20	-9.00	29.70	-9.00	12.29	-9.00	D2	11
	375.00	2.00	-9.00	249.60	381.80	-9.00	-9.00	17.90	27.40	-9.00	D	12
	400.00	2.00	224.80	161.60	298.40	-9.00	28.10	20.20	37.30	-9.00	D2	11
	408.00	2.00	-9.00	152.20	308.10	-9.00	-9.00	15.60	31.70	-9.00	D	
	420.00	3.00	-9.00	-9.00	-9.00	-9.00	-9.00	22.70	54.70	-9.00	D	12
	428.00	2.00	-9.00	168.30	249.50	-9.00	-9.00	13.20	19.50	-9.00	D	
	450.00	2.00	48.40	85.20	44.50	-9.00	10.90	19.19	10.02	-9.00	D2	11
	451.00	2.00	-9.00	137.80	227.90	-9.00	-9.00	12.40	20.50	-9.00	D	12
	480.00	4.00	-9.00	231.10	749.90	-9.00	-9.00	9.70	31.50	-9.00	D	12
	500.00	1.50	118.10	282.50	99.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	522.00	3.00	-9.00	-9.00	-9.00	-9.00	-9.00	27.70	54.60	-9.00	D	12
	600.00	5.00	-9.00	220.30	675.60	-9.00	-9.00	9.39	28.80	-9.00	D	12
	600.00	2.00	52.40	46.20	18.50	-9.00	8.34	7.36	2.94	-9.00	D2	11
	600.00	0.00	60.40	142.80	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	600.00	0.00	69.50	165.00	317.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	600.00	0.00	91.40	188.00	276.30	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	600.00	0.00	50.60	191.00	318.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	670.50	0.00	168.30	75.50	153.90	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	670.50	0.00	249.70	41.90	147.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	700.00	3.00	91.00	259.60	270.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	700.00	3.00	100.70	326.70	221.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	800.00	7.00	7.40	55.90	147.60	-9.00	0.23	1.75	4.61	-9.00	D	16
	900.00	3.00	300.40	358.60	94.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	900.00	3.00	197.70	68.70	121.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
AVG	543.63	2.43	121.26	178.88	252.92	-9.00	15.45	14.95	25.02	-9.00		
STD	164.53	2.17	80.68	87.34	172.14	-9.00	11.54	6.94	15.33	-9.00		
		M VOC	14.066									
		N/M VOC	107.194									
(g/l = x.1198)			14.527	21.430	30.300	—	20.718	19.914	33.552	—		g/kW-HR = x 1.341)
		M VOC	1.685				M VOC 2.403					
		N/M VOC	12.842				N/M VOC 18.315					
							34.067	32.744	55.169			(lb/10³ HP-HR = x 2.205)
							M VOC 3.952					
							N/M VOC 30.115					

RANGE :-
HP 300.00- 900.00
LOAD 15.00- 35.00

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE	Ref #
			VOC	CO	NOX	PART	VOC	CO	NOX	PART		
	300.00	30.10	-9.00	59.00	337.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	310.00	25.00	-9.00	54.20	374.10	-9.00	-9.00	1.92	12.60	-9.00	D	12
	310.00	25.00	-9.00	111.80	376.20	-9.00	-9.00	3.34	11.20	-9.00	D	
	340.00	25.00	-9.00	77.10	455.10	-9.00	-9.00	2.27	13.40	-9.00	D	
	340.00	25.00	30.40	56.80	107.00	-9.00	1.14	2.13	3.82	-9.00	D2	11
	378.00	25.00	-9.00	91.60	359.60	-9.00	-9.00	2.80	11.00	-9.00	D	12
	400.00	25.00	15.60	31.20	223.20	-9.00	0.43	0.86	6.42	-9.00	D2	11
	408.00	25.00	-9.00	65.50	417.50	-9.00	-9.00	2.02	12.90	-9.00	D	12
	420.00	25.00	-9.00	70.90	432.20	-9.00	-9.00	2.14	13.10	-9.00	D	
	428.00	25.00	-9.00	73.50	320.00	-9.00	-9.00	2.41	10.50	-9.00	D	
	450.00	25.00	11.10	47.40	131.70	-9.00	0.39	1.49	4.63	-9.00	D2	11
	451.00	25.00	-9.00	80.00	288.80	-9.00	-9.00	3.14	11.40	-9.00	D	12
	480.00	25.00	-9.00	54.90	288.90	-9.00	-9.00	1.91	9.52	-9.00	D	
	522.00	25.00	-9.00	69.70	423.90	-9.00	-9.00	2.19	13.30	-9.00	D	
	600.00	25.00	-9.00	55.20	271.20	-9.00	-9.00	1.87	9.20	-9.00	D	
	600.00	30.10	21.00	69.80	179.20	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	600.00	30.10	13.00	55.30	178.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	600.00	25.00	10.70	19.50	172.40	-9.00	0.33	0.60	5.31	-9.00	D2	11
	600.00	30.10	31.20	108.40	181.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
	600.00	30.10	14.40	69.90	159.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	900.00	22.00	-9.00	65.90	140.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	900.00	22.00	-9.00	55.80	191.60	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	900.00	22.00	6.30	63.60	165.30	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	900.00	22.00	27.30	64.40	185.30	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
AVG	530.71	25.56	18.10	65.27	264.82	-9.00	0.57	2.06	9.89	-9.00		
STD	192.73	2.57	8.40	20.05	108.01	-9.00	0.33	0.71	3.21	-9.00		
		Mvoc	2.100									
		N/Mvoc	16.000									
(g/l=X.1198)			2.168	7.919	31.725	—	0.764	2.762	13.262	—	(g/KW-HR=X1.341)	
		Mvoc	0.251			Mvoc	0.089					
		N/Mvoc	1.917			N/Mvoc	0.675					
							1.257	4.542	29.293	—	(lb/10³HP-HR=X2.205)	
						Mvoc	0.146					
						N/Mvoc	1.111					

:-

300.00- 900.00
45.00- 74.90

*** DIESEL ENGINES ***

RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE	Ref #
		VOC	CO	NOX	PART	VOC	CO	NOX	PART		
300.00	67.50	60.20	54.70	383.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
300.00	67.50	36.50	39.90	395.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
310.00	50.00	-9.00	40.40	-9.00	-9.00	-9.00	1.10	-9.00	-9.00	D	12
310.00	50.00	-9.00	63.00	375.00	-9.00	-9.00	1.61	9.60	-9.00	D	
340.00	50.00	-9.00	51.40	535.10	-9.00	-9.00	1.30	13.60	-9.00	D	
340.00	50.00	16.70	37.70	184.90	-9.00	0.47	1.06	5.20	-9.00	D2	11
378.00	50.00	-9.00	51.70	386.00	-9.00	-9.00	1.33	9.90	-9.00	D	12
400.00	50.00	8.78	23.80	316.70	-9.00	0.21	0.57	7.57	-9.00	D2	11
408.00	50.00	-9.00	42.00	541.10	-9.00	-9.00	1.08	14.00	-9.00	D	12
420.00	50.00	-9.00	58.20	500.30	-9.00	-9.00	1.45	12.50	-9.00	D	
428.00	50.00	-9.00	46.50	390.50	-9.00	-9.00	1.24	10.40	-9.00	D	
450.00	50.00	10.90	30.30	223.40	-9.00	0.30	0.83	6.12	-9.00	D2	11
451.00	50.00	-9.00	52.90	398.80	-9.00	-9.00	1.47	11.10	-9.00	D	12
480.00	50.00	-9.00	40.00	418.20	-9.00	-9.00	1.05	10.90	-9.00	D	
500.00	67.50	44.50	99.80	338.60	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
522.00	50.00	-9.00	55.70	494.80	-9.00	-9.00	1.46	13.00	-9.00	D	12
600.00	50.00	-9.00	39.70	379.10	-9.00	-9.00	1.06	10.40	-9.00	D	
600.00	74.00	9.50	24.60	327.00	-9.00	0.30	0.70	8.50	-9.00	ND	13
600.00	67.50	38.90	53.61	415.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
600.00	74.00	11.20	23.40	329.30	-9.00	0.30	0.60	8.60	-9.00	ND	
600.00	67.50	4.20	113.10	315.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
600.00	50.00	42.90	54.60	347.60	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
600.00	50.00	11.70	-9.00	291.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
600.00	67.50	37.00	45.10	453.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
600.00	45.00	13.60	22.90	431.00	-9.00	-9.00	0.50	11.70	-9.00	ND	
600.00	50.00	-9.00	135.40	390.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
600.00	67.00	10.30	20.70	387.00	-9.00	0.30	0.50	9.50	-9.00	ND	
600.00	45.00	11.30	20.30	391.80	-9.00	0.30	0.50	9.90	-9.00	ND	
600.00	67.00	3.80	22.90	360.30	-9.00	0.10	0.60	8.80	-9.00	ND	
600.00	67.50	36.90	52.50	463.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
600.00	74.00	9.50	26.00	327.00	-9.00	0.30	0.70	8.50	-9.00	ND	
600.00	50.00	8.40	16.80	269.30	-9.00	0.21	0.42	6.73	-9.00	D2	11
600.00	67.50	27.70	125.70	120.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
670.50	50.00	-9.00	39.40	223.10	-9.00	2.16	1.16	5.56	-9.00	ND	
700.00	60.00	8.10	37.00	422.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
700.00	50.00	10.70	86.90	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
700.00	50.00	9.60	19.90	458.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
700.00	60.00	7.70	31.30	455.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
700.00	60.00	9.80	15.80	487.40	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
800.00	55.00	4.10	46.30	249.80	-9.00	0.16	1.25	6.76	-9.00	D	12
820.00	50.00	8.40	24.20	259.90	-9.00	0.21	0.62	6.64	-9.00	D	
820.00	50.00	13.10	121.20	315.10	-9.00	0.35	3.22	8.38	-9.00	D	
860.00	50.00	5.90	51.50	240.80	-9.00	0.15	1.27	6.34	-9.00	D	
870.00	50.00	7.90	53.50	201.00	-9.00	0.08	-9.00	5.30	-9.00	D	
870.00	55.00	4.10	33.90	333.80	-9.00	0.11	0.57	8.56	-9.00	D	
900.00	51.00	4.90	102.20	282.90	-9.00	0.19	2.76	7.70	-9.00	D	
900.00	55.00	5.60	48.60	218.80	-9.00	0.14	1.25	5.63	-9.00	D	
900.00	55.00	10.30	59.70	299.80	-9.00	0.28	1.62	8.09	-9.00	D	
900.00	55.00	7.70	54.20	297.00	-9.00	0.21	1.41	7.73	-9.00	D	
900.00	55.00	5.10	47.60	219.20	-9.00	0.14	1.25	5.85	-9.00	D	
900.00	56.00	9.10	45.70	196.70	-9.00	0.24	1.35	5.22	-9.00	D	12
900.00	50.00	-9.00	75.50	350.50	-9.00	-9.00	2.04	9.50	-9.00	ND	13
900.00	50.00	26.40	65.90	465.70	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
900.00	50.00	-9.00	76.80	279.00	-9.00	-9.00	2.10	7.50	-9.00	ND	
900.00	60.00	7.80	85.40	344.00	-9.00	0.20	2.04	9.10	-9.00	ND	
616.50	55.91	15.48	52.36	348.67	-9.00	0.31	1.23	8.66	-9.00		
171.35	7.59	13.69	28.66	95.28	-9.00	0.46	0.61	2.37	-9.00		
	MVOC	1.796									
	N/MVOC	13.684									
g/l = X.XE-8		1.855	6.273	41.771	—	0.416	1.649	11.613	—		(g/kW-HR = X.XE-5)
	MVOC	0.215			MVOC	0.648					
	N/MVOC	1.680			N/MVOC	3.363					
						0.684	2.712	14.100	—		(lb/10**3-GAL = X.XE-5)
					MVOC	0.279					
					N/MVOC	0.605					

RANGE :-
HP 300.00- 900.00
LOAD 75.00- 100.00

*** DIESEL ENGINES ***

RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE	R.C II
		VOC	CO	NOX	PART	VOC	CO	NOX	PART		
300.00	79.00	19.30	46.90	326.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
300.00	79.00	13.50	43.50	258.30	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
300.00	79.00	23.10	83.20	213.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
300.00	79.00	27.80	60.30	301.20	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
310.00	100.00	-9.00	205.20	583.60	-9.00	-9.00	5.95	14.40	-9.00	D	
310.00	75.00	-9.00	36.90	546.20	-9.00	-9.00	0.93	13.70	-9.00	D	12
310.00	100.00	-9.00	-9.00	274.10	-9.00	-9.00	-9.00	7.40	-9.00	D	
310.00	75.00	-9.00	137.50	405.60	-9.00	-9.00	3.45	10.20	-9.00	D	
325.00	100.00	8.60	58.10	358.10	17.24	0.20	1.40	8.70	0.41	D2	7
340.00	100.00	-9.00	-9.00	455.30	-9.00	-9.00	-9.00	11.90	-9.00	D	12
340.00	75.00	-9.00	107.40	583.70	-9.00	-9.00	2.67	14.50	-9.00	D	12
340.00	75.00	10.80	35.60	281.70	-9.00	0.27	0.89	7.04	-9.00	D2	11
340.00	100.00	8.56	64.40	396.90	-9.00	0.21	1.58	9.74	-9.00	D2	11
365.00	100.00	6.53	60.80	309.00	14.60	0.20	1.50	7.60	0.36	D2	7
378.00	100.00	-9.00	456.80	376.00	-9.00	-9.00	11.60	9.57	-9.00	D	12
378.00	75.00	-9.00	73.80	428.50	-9.00	-9.00	1.92	10.60	-9.00	D	12
400.00	75.00	7.50	25.60	407.00	-9.00	0.17	0.58	9.23	-9.00	D2	11
400.00	100.00	8.84	44.20	472.70	-9.00	0.20	1.00	10.70	-9.00	D2	11
408.00	100.00	-9.00	219.90	670.10	-9.00	-9.00	5.49	16.70	-9.00	D	
408.00	75.00	-9.00	62.60	675.50	-9.00	-9.00	1.55	16.80	-9.00	D	12
420.00	100.00	-9.00	413.90	538.60	-9.00	-9.00	9.95	13.00	-9.00	D	
420.00	75.00	-9.00	61.00	579.30	-9.00	-9.00	1.46	13.90	-9.00	D	
428.00	100.00	-9.00	215.00	417.90	-9.00	-9.00	5.45	10.60	-9.00	D	
428.00	75.00	-9.00	54.30	437.30	-9.00	-9.00	1.37	11.60	-9.00	D	
450.00	75.00	9.97	27.10	341.70	-9.00	0.25	0.68	8.57	-9.00	D2	11
450.00	100.00	6.19	32.20	459.90	-9.00	0.15	0.78	11.14	-9.00	D2	11
451.00	100.00	-9.00	123.20	458.50	-9.00	-9.00	3.14	11.70	-9.00	D	12
451.00	75.00	-9.00	50.30	464.70	-9.00	-9.00	1.31	12.10	-9.00	D	
475.00	100.00	6.64	60.90	198.90	13.70	0.20	1.60	5.20	0.36	D2	7
480.00	100.00	-9.00	198.20	607.30	-9.00	-9.00	4.60	14.70	-9.00	D	12
480.00	75.00	-9.00	34.00	530.60	-9.00	-9.00	0.91	12.60	-9.00	D	
500.00	79.00	22.80	84.20	269.20	-9.00	-9.00	-9.00	-9.00	-9.00	ND	13
522.00	100.00	-9.00	328.00	585.30	-9.00	-9.00	8.65	14.40	-9.00	D	12
522.00	75.00	-9.00	60.90	577.60	-9.00	-9.00	1.51	14.40	-9.00	D	
550.00	100.00	3.83	52.40	253.70	3.83	0.10	1.40	6.50	0.10	D2	7
600.00	100.00	-9.00	156.10	600.00	-9.00	-9.00	3.54	14.80	-9.00	D	12
600.00	75.00	-9.00	33.40	484.20	-9.00	-9.00	0.54	12.20	-9.00	D	
600.00	78.00	12.00	25.50	340.10	-9.00	0.30	0.70	8.70	-9.00	ND	13
600.00	75.00	11.60	25.60	350.40	-9.00	0.30	0.70	9.40	-9.00	ND	
600.00	75.00	11.20	17.10	325.80	-9.00	0.30	0.50	8.40	-9.00	ND	
600.00	100.00	6.12	34.60	508.30	-9.00	0.14	0.79	11.62	-9.00	D2	11
600.00	75.00	6.04	15.50	396.50	-9.00	0.14	0.36	9.19	-9.00	D2	
600.00	75.00	11.90	25.90	350.30	-9.00	0.30	0.70	9.40	-9.00	ND	
600.00	79.00	12.10	30.70	306.70	-9.00	0.30	0.80	7.80	-9.00	ND	
600.00	80.00	12.50	27.10	319.10	-9.00	0.30	0.70	8.10	-9.00	ND	
600.00	79.00	10.60	29.40	317.60	-9.00	0.30	0.70	7.80	-9.00	ND	13
600.00	76.00	15.50	24.90	294.80	-9.00	0.40	0.60	7.50	-9.00	ND	
670.50	80.00	49.50	124.90	446.60	-9.00	-9.00	-9.00	-9.00	0.72	ND	
670.50	80.00	-9.00	-9.00	-9.00	32.50	-9.00	-9.00	-9.00	0.79	ND	
670.50	90.00	41.60	150.70	460.90	-9.00	1.12	4.07	12.40	-9.00	ND	

(CONTINUED)

	670.50	80.00	-9.00	92.80	399.20	32.50	-9.00	2.25	9.67	0.79	ND
	670.50	80.00	48.40	51.70	-9.00	-9.00	1.37	1.47	-9.00	-9.00	ND
	825.00	100.00	2.40	32.60	288.80	1.97	0.10	0.52	7.25	0.05	D2
	850.00	100.00	2.80	48.10	25.70	3.94	0.10	1.20	6.10	0.09	D2
AVG	483.64	86.00	14.61	89.51	404.83	15.04	0.31	2.29	10.64	0.41	
STD	138.73	11.38	12.15	94.53	130.86	11.38	0.29	2.47	2.87	0.28	
		MVOC	1.635								
		N/MVOC	12.915								
(g/l=X.1198)			1.750	10.723	48.980	1.802	0.416	3.071	14.268	0.550	(g/kw-HR=X1.341)
		MVOC	0.203				MVOC 0.048				
		N/MVOC	1.547				N/MVOC 0.368				
							0.684	5.049	23.461	0.904	(lb/10^3HP-HR=X2.205)
							MVOC 0.079				
							N/MVOC 0.605				

RANGE :-
HP 1000.00- 3600.00
LOAD 0.00- 25.00 ✓

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	G/HP-HR VOC	CO	NOX	PART	FUEL TYPE	
	1018.00	25.00	-9.00	33.80	387.90	-9.00	-9.00	1.08	12.40	-9.00	D	12
	1150.00	25.00	-9.00	20.50	388.20	-9.00	-9.00	0.71	13.40	-9.00	D	12
	1200.00	25.00	103.90	32.90	487.60	-9.00	2.66	0.85	12.60	-9.00	D	
	1200.00	14.00	107.50	39.70	553.50	-9.00	2.92	1.08	15.10	-9.00	D	
	1200.00	15.00	130.80	47.80	532.60	-9.00	3.56	1.30	14.50	-9.00	D	
	1200.00	4.00	-9.00	190.90	698.20	-9.00	-9.00	5.91	21.60	-9.00	D	
	1200.00	8.00	130.70	74.20	565.70	-9.00	3.95	2.24	17.10	-9.00	D	16
	1200.00	25.00	107.20	33.90	484.40	-9.00	2.77	0.87	12.50	-9.00	D	
	1200.00	21.00	113.20	32.10	492.40	-9.00	2.92	0.83	12.70	-9.00	D	
	1200.00	8.00	142.40	73.10	583.00	-9.00	4.30	2.21	17.60	-9.00	D	
	1200.00	24.00	102.70	32.20	505.60	-9.00	2.65	0.83	13.10	-9.00	D	
	1580.00	15.00	-9.00	135.60	366.60	-9.00	-9.00	-9.00	-9.00	2.30*	ND	
	1580.00	15.00	-9.00	109.10	376.00	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	2500.00	25.00	14.90	108.30	303.80	-9.00	0.40	3.20	8.80	-9.00	ND	
	2500.00	25.00	15.40	128.90	357.40	-9.00	0.50	4.50	12.60	-9.00	ND	
	2500.00	25.00	23.10	113.40	295.10	-9.00	0.70	3.30	8.60	-9.00	ND	
	2500.00	25.00	12.50	155.80	348.80	-9.00	0.40	5.50	12.30	-9.00	ND	13
	2500.00	15.00	36.10	65.00	473.30	-9.00	0.50	0.60	5.90	-9.00	ND	
	2500.00	15.00	13.70	58.50	320.00	-9.00	0.30	1.30	7.00	-9.00	ND	
	2500.00	15.00	16.70	58.60	556.40	-9.00	0.20	0.70	6.90	-9.00	ND	
	2500.00	15.00	23.60	59.60	328.80	-9.00	0.50	1.30	7.10	-9.00	ND	
	3600.00	15.00	55.40	141.50	331.60	71.20*	1.70	3.20	7.50	1.61*	ND	
	3600.00	15.00	65.40	155.60	402.40	-9.00	1.60	3.60	9.20	-9.00	ND	
	3600.00	25.00	23.90	21.00	363.10	-9.00	0.70	0.60	10.50	-9.00	ND	
	3600.00	25.00	27.10	35.10	354.20	-9.00	0.90	1.10	11.10	-9.00	ND	
AVG	2021.12	18.68	63.31	78.28	434.26	~~71.20~~ 50.5	1.70	2.04	11.74	~~1.96~~ 1.37		
STD	895.06	6.46	46.71	49.04	104.36	0.00	1.34	1.57	3.81	0.34		
		M-VOC	1.3W				0.197					
		NM-VOC	15.966				1.503					
(g/L = x.1198)			7.584	9.378	51.0W	6.050	2.180	2.736	13.743	1.837		(g/KW-HR = x 1.341)
		M-VOC	0.680				0.245					
		NM-VOC	6.704				1.935					
							3.748	1.498	X.181	3.021		(lb/10HP-HR x 2.205)
						M-VOC	0.43					
						NM-VOC	3.313					

* To be combined with 35-55% and 75-100% load data

RANGE :-
HP 1000.00- 3600.00
LOAD 35.00- 55.00 ✓

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	G/HP-HR VOC	CO	NOX	PART	FUEL TYPE	
	1018.00	50.00	-9.00	26.80	462.90	-9.00	-9.00	0.69	12.40	-9.00	D	12
	1150.00	50.00	-9.00	26.00	495.40	-9.00	-9.00	0.71	13.50	-9.00	D	12
	1200.00	38.00	101.10	54.00	508.90	-9.00	2.60	1.39	13.10	-9.00	D	16
	1200.00	38.00	86.10	56.40	523.30	-9.00	2.22	1.45	13.50	-9.00	D	16
	1580.00	55.00	-9.00	44.60	625.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	1580.00	55.00	-9.00	44.60	621.10	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	2500.00	55.00	12.10	69.80	389.30	-9.00	0.60	3.30	18.10	-9.00	ND	
	2500.00	55.00	16.80	78.30	391.70	-9.00	0.80	3.70	18.30	-9.00	ND	13
	3600.00	55.00	48.20	20.90	354.60	-9.00	1.21	0.52	8.90	-9.00	ND	
	3600.00	55.00	31.70	72.80	-9.00	30.10*	0.80	1.80	9.70	0.75*	ND	
	3600.00	55.00	25.50	35.90	308.70	-9.00	0.60	0.90	7.60	-9.00	ND	
AVG	2138.91	51.00	45.93	48.19	470.10	~~30.10~~ 50.50	1.26	1.91	12.79	~~0.75~~ 1.37		
STD	1012.98	6.41	32.24	18.95	102.00	0.00	0.76	1.09	3.52	0.00		
		M-VOC	5.378				0.186					
		W/M-VOC	40.604				1.114					
	(g/l = x.1198)		5.508	5.577	56.318	6.050	1.690	2.159	17.151	1.837		(g/KW-HR = x 1.341)
		M-VOC	6.639				0.196					
		W/M-VOC	4.869				1.494					
							2.778	3.550	28.444	3.021		(lb/10^3 HP-HR = x 2.205)
						M-VOC	0.334					
						W/M-VOC	2.452					

* To be combined with 0-25% and 75-100% load data

RANGE :-
HP 1000.00- 3600.00
LOAD 75.00- 100.00

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE	
			VOC	CO	NOX	PART	VOC	CO	NOX	PART		
	1018.00	100.00	-9.00	294.40	388.00	-9.00	-9.00	-9.00	9.85	-9.00	D	12
	1018.00	75.00	-9.00	84.90	486.50	-9.00	-9.00	2.10	12.00	-9.00	D	
	1150.00	100.00	-9.00	216.90	454.00	-9.00	-9.00	5.56	11.60	-9.00	D	
	1150.00	75.00	-9.00	88.90	503.50	-9.00	-9.00	2.30	13.00	-9.00	D	
	1580.00	79.00	19.00	231.60	-9.00	-9.00	-9.00	-9.00	-9.00	1.30*	ND	13
	1580.00	79.00	22.70	226.30	523.60	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	1580.00	79.00	13.30	255.80	449.80	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	1580.00	79.00	13.20	254.50	442.50	-9.00	-9.00	-9.00	-9.00	-9.00	ND	
	2500.00	79.00	24.80	137.60	375.40	-9.00	0.80	4.50	12.20	-9.00	ND	
	2500.00	79.00	26.80	77.40	413.30	-9.00	0.90	2.50	13.50	-9.00	ND	
	2500.00	79.00	14.00	78.10	402.40	-9.00	0.60	2.50	13.10	-9.00	ND	
	2500.00	79.00	19.50	90.40	407.00	-9.00	0.60	2.90	13.20	-9.00	ND	
	3600.00	79.00	27.60	68.80	287.80	39.30*	0.70	1.60	6.80	0.93*	ND	
	3600.00	79.00	24.80	69.60	295.60	39.30*	0.60	1.70	7.00	0.93*	ND	
	3600.00	79.00	36.00	48.90	337.50	72.60*	0.90	1.20	8.30	1.79*	ND	
AVG	2097.07	81.27	21.97	148.27	411.94	~~50.40~~ 50.50	0.71	2.69	10.96	~~1.24~~ 1.37		
STD	917.17	7.47	6.73	83.77	69.19	15.70	0.15	1.29	2.42	0.35		
		M-VOC	7.58				0.08					
		NM-VOC	19.43				0.67					
(g/L = x.1198)			2.63	17.763	49.350	6.050	0.95	3.607	14.691	1.837		(g/KW-HR = x1.341)
		M-VOC	0.71				0.110					
		NM-VOC	2.579				0.84					
							1.566	5.93	21.169	3.021		(lb/10³ HP-HR = x2.205)
						M-VOC	0.18					
						NM-VOC	1.74					

* To be combined with 0-25% and 35-55% load data

B-3. Residual Oil Fired Motorships Data for AP-42 Section Table 3.2.3-5

Note: Computer data are in terms of g/metric Hp-hr as opposed to English Horsepower units for residual oil fired motorships. This is due to the data source's use of metric units (Reference 10). The conversion factor for metric HP is 1.361 KW/metric HP as opposed to 1.341 KW/HP (English).

RANGE :-
HP 0.00- 4999.90 ✓
LOAD 100.00- 100.00

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE
			VOC	CO	NOX	PART	VOC	CO	NOX	PART	
	545.00	100.00	16.10	48.90	268.30	-9.00	0.31	0.94	5.16	-9.00	FU6
	680.00	100.00	16.10	48.90	268.30	-9.00	0.31	0.94	5.16	-9.00	FU6
	815.00	100.00	16.10	48.90	268.30	-9.00	0.31	0.94	5.16	-9.00	FU6
	950.00	100.00	16.10	48.90	268.30	-9.00	0.31	0.94	5.16	-9.00	FU6
	1090.00	100.00	16.10	48.90	268.30	-9.00	0.31	0.94	5.16	-9.00	FU6
	1225.00	100.00	16.10	48.90	268.30	-9.00	0.31	0.94	5.16	-9.00	FU6
	1630.00	100.00	16.30	49.30	270.60	-9.00	0.31	0.94	5.16	-9.00	FU6
	1800.00	100.00	43.80	58.40	553.80	-9.00	0.81	1.08	10.30	-9.00	FU6
	1900.00	100.00	16.30	49.30	270.80	-9.00	0.31	0.94	5.16	-9.00	FU6
	2180.00	100.00	16.30	49.30	270.80	-9.00	0.31	0.94	5.16	-9.00	FU6
	2400.00	100.00	43.80	58.40	553.80	-9.00	0.81	1.08	10.30	-9.00	FU6
	2450.00	100.00	16.30	49.30	270.80	-9.00	0.31	0.94	5.16	-9.00	FU6
	2700.00	100.00	43.80	58.40	553.80	-9.00	0.81	1.08	10.30	-9.00	FU6
	3000.00	100.00	20.00	100.20	417.00	-9.00	0.36	1.80	7.49	-9.00	FU6
	3500.00	100.00	20.00	100.20	417.00	-9.00	0.36	1.80	7.49	-9.00	FU6
	3600.00	100.00	44.00	58.60	556.60	-9.00	0.81	1.08	10.30	-9.00	FU6
	4000.00	100.00	20.00	100.20	417.00	-9.00	0.36	1.80	7.49	-9.00	FU6
	4500.00	100.00	25.80	37.30	498.90	-9.00	0.45	0.65	8.69	-9.00	FU6
	4500.00	100.00	20.00	100.20	417.00	-9.00	0.36	1.80	7.49	-9.00	FU6
	4800.00	100.00	44.00	58.60	556.60	-9.00	0.81	1.08	10.30	-9.00	FU6
AVG	2413.25	100.00	24.35	61.06	381.73	-9.00	0.45	1.13	7.09	-9.00	
STD	1334.19	0.00	11.52	20.21	121.47	-9.00	0.21	0.35	2.14	-9.00	

All American MAN DATA

NON METHANE VOC 2.83✓ 20.111 (NON-METHANE) 0.396

(g/L - x0.0018) 2.917 7.315 45.731 0.613 1.538 9.612 (g/kW-hr = X 1.3613)

M-VOC 0.334 N-M-VOC 0.971
N-M VOC 2.179 N-M-VOC 2.582

1.006 2.526 15.846 (lb/10³HP-HR - X2.235)

M-VOC 0.149
N-M-VOC 0.189

RANGE :-
HP 5000.00- 9999.90
LOAD 100.00- 100.00 ✓

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	lb POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE
			VOC	CO	NOX	PART	VOC	CO	NOX	PART	
	5250.00	100.00	25.80	37.30	498.90	-9.00	0.45	0.65	8.69	-9.00	FO6
	5400.00	100.00	44.00	58.60	556.60	-9.00	0.81	1.08	10.30	-9.00	FO6
	6000.00	100.00	25.80	37.30	498.90	-9.00	0.45	0.65	8.69	-9.00	FO6
	6000.00	100.00	20.40	101.80	423.40	-9.00	0.36	1.80	7.49	-9.00	FO6
	6330.00	100.00	49.30	34.20	650.40	-9.00	0.85	0.59	11.20	-9.00	FO6
	6750.00	100.00	25.80	37.30	498.90	-9.00	0.45	0.65	8.69	-9.00	FO6
	7000.00	100.00	20.40	101.80	423.40	-9.00	0.36	1.80	7.49	-9.00	FO6
	7385.00	100.00	49.30	34.20	650.40	-9.00	0.85	0.59	11.20	-9.00	FO6
	8000.00	100.00	20.40	101.80	423.40	-9.00	0.36	1.80	7.49	-9.00	FO6
	8260.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	FO6
	8260.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	FO6
	8440.00	100.00	49.30	34.20	650.40	-9.00	0.85	0.59	11.20	-9.00	FO6
	9000.00	100.00	26.40	38.10	509.50	-9.00	0.45	0.65	8.69	-9.00	FO6
	9000.00	100.00	20.40	101.80	423.40	-9.00	0.36	1.80	7.49	-9.00	FO6
	9495.00	100.00	49.30	34.20	650.40	-9.00	0.85	0.59	11.20	-9.00	FO6
AVG	7371.33	100.00	32.82	57.89	527.54	-9.00	0.57	1.11	9.11	-9.00	
STD	1333.86	0.00	12.46	29.90	90.89	-9.00	0.20	0.55	1.44	-9.00	

M-VOC = 3.807
N-M-VOC = 29.013

M-VOC = 0.066
N-M-VOC = 0.504

ALL AMERICAN MAN DATA

(g/L = x 0.1198) 3.932 6.935 63.199 0.776 1.311 12.101 G/KW-HR = x 1.3613

M-VOC = 0.456
N-M-VOC = 3.476

M-VOC = 0.096
N-M-VOC = 0.686

1.274 2.481 20.361 lb/10**3 HP-HR = x 2.235

M-VOC = 0.148
N-M-VOC = 1.136

RANGE 1-
HP 10000.00-14999.90
LOAD 100.00- 100.00 ✓

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL VOC	CO	NOX	PART	G/HP-HR VOC	CO	NOX	PART	FUEL TYPE
	10325.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	FU6
	10325.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	FU6
	10500.00	100.00	26.40	38.10	509.50	-9.00	0.45	0.65	8.69	-9.00	FU6
	10550.00	100.00	50.40	35.00	664.30	-9.00	0.85	0.59	11.20	-9.00	FU6
	12000.00	100.00	26.40	38.10	509.50	-9.00	0.45	0.65	8.69	-9.00	FU6
	12390.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	FU6
	12390.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	FU6
	12660.00	100.00	50.40	35.00	664.30	-9.00	0.85	0.59	11.20	-9.00	FU6
	13500.00	100.00	26.40	38.10	509.50	-9.00	0.45	0.65	8.69	-9.00	FU6
	14455.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	FU6
	14455.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	FU6
	14770.00	100.00	50.40	35.00	664.30	-9.00	0.65	0.59	11.20	-9.00	FU6
	14770.00	100.00	37.90	29.00	296.00	33.90	0.67	0.51	5.20	0.60	FU6
AVG	12545.38	100.00	38.33	35.47	545.34	~~33.90~~	0.60	1.11	8.88	~~0.60~~	
STD	1675.32	0.00	11.11	3.01	124.49	0.00	0.15	0.55	1.54	0.00	
			M-VOC : 4.486 N-M-VOC : 33.884				0.070 0.130				
(g/L = x .1198)			4.594	4.249	65.337	4.061 ↓ Data pt excluded less than 2pts	0.817	1.511	12.088	0.817 ↓ Data pt excluded less than 2pts	
			M-VOC 0.439 N-M-VOC 4.059				M-VOC : 0.095 N-M-VOC : 0.722				
							1.381	2.481	19.841	1.381 ↓ Data pt excluded less than 2 pts.	
							M-VOC 0.156 N-M-VOC 1.185				

All AMERICAN MAN DATA

(g/kw-hr = x 1.3413)

(lb/10³hp-hr = x 2.235)

RANGE :- .
HP 15000.00-19999.90
LOAD 60.00- 100.00

*** DIESEL ENGINES ***

RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE
		VOC	CO	NOX	PART	VOC	CO	NOX	PART	
15990.00	60.00	-9.00	-9.00	-9.00	-9.00	0.40	0.90	8.89	-9.00	F06
15590.00	85.00	-9.00	-9.00	-9.00	-9.00	0.50	2.60	8.59	-9.00	F06
15990.00	60.00	-9.00	-9.00	-9.00	-9.00	0.50	1.60	8.74	-9.00	F06
15990.00	85.00	-9.00	-9.00	-9.00	-9.00	0.40	1.20	8.74	-9.00	F06
15990.00	60.00	-9.00	-9.00	-9.00	-9.00	0.40	0.90	8.89	-9.00	F06
15990.00	85.00	-9.00	-9.00	-9.00	-9.00	0.50	2.60	8.59	-9.00	F06
15990.00	60.00	-9.00	-9.00	-9.00	-9.00	0.50	1.60	8.74	-9.00	F06
15990.00	85.00	-9.00	-9.00	-9.00	-9.00	0.40	1.20	8.74	-9.00	F06
16520.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	F06
16520.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	F06
16880.00	100.00	50.40	35.00	664.30	-9.00	0.85	0.59	11.20	-9.00	F06
18585.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	F06
18585.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	F06
18990.00	100.00	50.40	35.00	664.30	-9.00	0.85	0.59	11.20	-9.00	F06
AVG 16665.71	84.29	50.40	35.00	664.30	-9.00	0.53	1.50	9.00	-9.00	
STD 1108.60	16.57	0.00	0.00	0.00	-9.00	0.14	0.62	0.91	-9.00	

ALL AMERICAN MAN DATA

N-VOC 5.884
N-M-VOC 22.514

0.027
0.468

(g/L = x.1198) 6.038 4.193 79.583 0.722 2.042 12.262 (g/kw-hr = x 1.3613)

N-VOC 0.900
N-M-VOC 3.938

N-VOC 0.084
N-M-VOC 0.638

1.186 3.362 20.186 (lb/10³ hp-hr = x 2.236)

N-VOC 0.137
N-M-VOC 1.042

*

RANGE :-
HP 20000.00-30000.00
LOAD 60.00- 100.00

*** DIESEL ENGINES ***

	RATED HP	LOAD (%)	LB POLLUTANT/10**3 GAL				G/HP-HR				FUEL TYPE
			VOC	CO	NOX	PART	VOC	CO	NOX	PART	
	20650.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	F06
	20650.00	100.00	-9.00	-9.00	-9.00	-9.00	0.53	1.70	8.43	-9.00	F06
	21320.00	85.00	-9.00	-9.00	-9.00	-9.00	0.50	2.60	8.59	-9.00	F06
	21320.00	85.00	-9.00	-9.00	-9.00	-9.00	0.40	1.20	8.74	-9.00	F06
	21320.00	85.00	-9.00	-9.00	-9.00	-9.00	0.40	1.20	8.74	-9.00	F06
	21320.00	60.00	-9.00	-9.00	-9.00	-9.00	0.40	0.90	8.89	-9.00	F06
	21320.00	60.00	-9.00	-9.00	-9.00	-9.00	0.50	1.60	8.74	-9.00	F06
	21320.00	60.00	-9.00	-9.00	-9.00	-9.00	0.50	1.60	8.74	-9.00	F06
	21320.00	60.00	-9.00	-9.00	-9.00	-9.00	0.40	0.90	8.89	-9.00	F06
	21320.00	85.00	-9.00	-9.00	-9.00	-9.00	0.50	2.60	8.59	-9.00	F06
	29440.00	60.00	-9.00	-9.00	-9.00	-9.00	0.20	1.00	9.97	-9.00	F06
	29440.00	85.00	-9.00	-9.00	-9.00	-9.00	0.10	1.20	9.97	-9.00	F06
	29440.00	85.00	-9.00	-9.00	-9.00	-9.00	0.10	1.20	9.97	-9.00	F06
	29440.00	60.00	-9.00	-9.00	-9.00	-9.00	0.20	1.00	9.97	-9.00	F06
	29440.00	85.00	-9.00	-9.00	-9.00	-9.00	0.20	1.10	9.97	-9.00	F06
	29440.00	60.00	-9.00	-9.00	-9.00	-9.00	0.20	1.00	9.97	-9.00	F06
	29440.00	85.00	-9.00	-9.00	-9.00	-9.00	0.20	1.10	9.97	-9.00	F06
	29440.00	60.00	-9.00	-9.00	-9.00	-9.00	0.20	1.00	9.97	-9.00	F06
AVG	24854.45	75.56	-9.00	-9.00	-9.00	-9.00	0.34	1.39	9.25	-9.00	
STD	4106.31	14.61	-9.00	-9.00	-9.00	-9.00	0.15	0.52	0.65	-9.00	

All American Man Data

0.039
0.391

0.463 1.893 12.19V (g/KW-HR = x 1.3613)

M-VOC 0.058
W-M-VOC 0.409

0.760 3.107 20.674 (lb/10³ HP-HR = x 2.235)

M-VOC 0.058
W-M-VOC 0.672

APPENDIX C

GASOLINE POWERED INBOARD PLEASURE CRAFT FOR AP-42

TABLE 3.2.3-7

TABLE C-1

GASOLINE POWERED PLEASURE CRAFT EMISSION FACTORS
Idle Mode[a]

Engine Size HP	VOC ($lb/10^3$ gal)	CO ($lb/10^3$ gal)	NO_x ($lb/10^3$ gal)
4	2,796	3,417	0
9.5	3,140	2,851	0.78
35	3,104	3,043	1.81
65	3,349	2,883	0.90
AVG	3,097	3,049	0.87
	(235/2862)[b]		

[a]Reference 25. Each emission value represents multiple tests on a single engine.

[b]Methane/nonmethane VOC split derived from Table 9-06-021B, Reference 3.

Metric Units	Ch_4	NMVOC	CO	NO_x
g/l	28.2	342.9	365	0.10

TABLE C-2

GASOLINE POWERED INBOARD PLEASURE CRAFT EMISSION FACTORS
Less than or equal to 10 percent of load

Value (% Load)	VOC		CO		NO_x	
	(g/HP/hr)	(lb/10^3 gal)	(g/HP/hr)	(lb/10^3 gal)	(g/HP/hr)	(lb/10^3 gal)
1.3[a]	3,520	2,364	5,500	3,693	2.00	1.34
5.8[a]	730	1,869	1,317	3,371	0.87	2.22
1.8[a]	2,429	2,765	2,776	3,160	0.59	0.67
10.0[a]	672	2,189	1,001	3,263	0.74	2.40
1.4[a]	1,492	2,375	2,160	3,468	1.20	1.91
8.3[a]	359	1,818	797	4,038	0.59	2.97
1.4[a]	2,411	2,779	2,878	3,317	0.89	1.02
8.0[a]	381	2,248	556	3,281	0.15	0.91
2.3[b]	2,759	c	3,879	c	0.46	c
1.6[b]	1,476	c	667	c	0.95	c
9.2[b]	299	c	126	c	0.20	c
1.3[b]	1,814	2,774	1,281	1,960	0.80	1.22
8.0[b]	412	2,068	358	1,798	0.20	0.99
2.3[b]	817	c	1,022	c	0.65	c
1.8[b]	420	c	769	c	0.28	c
AVG.	1,333[d]	2,325[d]	1,672	3,132	0.70	1.60

[a]Reference 25.
[b]Reference 26.
[c]Not Available.
[d]Methane is 101 g/HP/hr or 177 lb/10^3 gal and NMVOC is 1232 g/HP/hr or 2148 lb/10^3 gal as derived from Table 9-06-021B, Reference 3.

Conversions	Pollutant			
	CH_4	NMVOC	CO	NO_x
g/kw/hr	135	1652	2242	0.94
1/10^3HP/hr	223	2717	3688	1.54
g/l	21.2	257	375	0.19

TABLE C-3

PLEASURE CRAFT EMISSION FACTORS
Greater than 10 percent but less than or equal to 50 percent of load

Value (% Load)	VOC		CO		NO_x	
	(g/HP/hr)	(lb/10^3 gal)	(g/HP/hr)	(lb/10^3 gal)	(g/HP/hr)	(lb/10^3 gal)
18.8[a]	283	1,501	632	3,357	0.80	4.25
43.5[a]	186	1,637	337	2,965	0.75	6.57
27.3[a]	319	1,846	587	3,392	0.73	4.24
22.6[a]	196	1,716	509	4,450	0.44	3.87
46.0[a]	115	1,471	358	4,580	0.43	5.49
20.0[a]	163	1,692	373	3,871	0.25	2.51
44.9a	93.5	1,503	172	2,770	0.66	10.6
36.3[b]	339	c	551	c	0.47	c
25.3[b]	137	c	82.2	c	0.15	c
22.0[b]	244	2,511	286	2,946	0.16	1.67
45.1[b]	120	2,135	238	4,214	0.14	2.53
13.2[b]	180	c	133	c	0.32	c
36.3[b]	74.1	c	121	c	0.43	c
10.1[b]	185	c	111	c	0.21	c
27.9[b]	67.3	c	112	c	0.34	c
AVG.	180.1[d]	1,779[d]	307	3,616	0.42	4.6

[a]Reference 25.
[b]Reference 26.
[c]Not available.
[d]13.7 g/HP/hr or 135 lb/10^3 gal methane and 166 g/HP/hr or 1644 lb/10^3 gal nonmethane VOC as derived from Table 9-06-021B, Reference 3.

Conversions	Pollutant			
	CH_4	NMVOC	CO	NO_x
g/Kw/hr	18.4	223	412	0.563
lb/10^3HP/hr	30.2	366	677	0.926
g/l	16.2	197	433	0.551

TABLE C-4

GASOLINE POWERED INBOARD PLEASURE CRAFT EMISSION FACTORS
Greater than 50 percent but less than or equal 100 percent of load

Value (% Load)	VOC		CO		NO_x	
	(g/HP/hr)	(lb/10^3 gal)	(g/HP/hr)	(lb/10^3 gal)	(g/HP/hr)	(lb/10^3 gal)
68.3[a]	211	2,282	256	2,764	2.01	21.7
56.2[a]	152	1,505	316	3,128	0.71	7.03
83.2[a]	109	1,332	294	3,598	0.86	10.6
81.1[a]	101	1,510	328	4,882	0.34	5.09
70.2[a]	102	1,697	135	2,246	1.83	30.4
82.2[a]	119	1,869	167	2,627	1.53	24.0
74.5[b]	156	c	204	c	0.50	c
51.9[b]	80	c	147	c	0.13	c
90.7[b]	55.2	c	113	c	0.20	c
78.8[b]	55.3	1,263	172	3,933	0.20	4.47
74.5[b]	65.4	c	193	c	0.37	c
57.2[b]	63.3	c	201	c	0.24	c
AVG.	106 (8.1/97.9)[d]	1,637 (124/1513)[d]	211	3,311	0.74	14.8

[a]Reference 25.
[b]Reference 26.
[c]Not available.
[d]Methane/nonmethane VOC splits derived from Table 9-06-02B, Reference 3.

Conversions	Pollutant			
	CH_4	NMVOC	CO	NO_x
g/Kw/hr	10.9	131	283	0.99
lb/10^3HP/hr	17.9	216	465	1.63
g/l	14.9	181	397	1.77

TABLE C-5

GASOLINE POWERED INBOARD PLEASURE CRAFT EMISSION FACTORS
100 percent of load[a]

Engine Size (HP)[b]	VOC (g/HP/hr)	CO (g/HP/hr)	NO_x (g/HP/hr)
50	93	153	C
65	69.2	143	0.42
70	52.9	180	0.30
40	62.5	156	0.48
40	51.3	105	0.52
AVG.	65.8	147.4	0.43
	(5.0/60.8)[d]		

[a]Reference 25.
[b]Tests conducted for five different engines.
[c]Not available.

Conversions	Pollutant			
	CH_4	NMVOC	CO	NO_x
g/Kw/hr	6.7	81.5	198	0.58
lb/10^3HP/hr	11.0	134	325	0.95

APPENDIX D

EMISSION DATA SUMMARIES FROM REFERENCED DATA SOURCES

NOTE: Pollutant concentration, emissions and table numbers are expressed in terms as reported in the referenced document.

1. American MAN Heavy Fuel Fired Diesel Engine Data

References 9 and 10

AMERICAN MAN 1978 DIESEL ENGINE DATA[a]

Engine Classification	Full Load	Fuel Sulfur Content (%)	Load (%)	SO_2	NO	ASH	NO_x	CO	HC	Consumption (kg/KW/hr)
				gm/KW/hr						
14V 52/55A (four stroke)	10850 KW (14770 HP)	2.16	100	8.5	-	0.8	7.129	.698	.913	0.196
KSZ 70/125B (two stroke)	1520 KW/cyl (2065 HP/cyl) 4-10 cyl	2.16	100	9.2	7.44	-	-	2.28	0.72	
		1.0	100	4.3	7.44					
KSZ 78/155B	1960 KW/cyl (2665 HP/cyl) (6 + 8 cyl)	2.5	85	11.1	7.7	-	-	1.7	0.6	
		4.0	85	17.7	7.7	-	-	1.7	0.6	
		2.5	60	11.2	7.9	-	-	1.2	0.6	
		4.0	60	17.9	7.9	-	-	1.2	0.6	
KSZ 78/155BL	1960 KW/cyl (2665 HP/cyl) (6 + 8 cyl	2.5	85	11.2	7.6	-	-	3.5	0.7	
		4.0	85	17.8	7.6	-	-	3.5	0.7	
		2.5	60	11.2	7.8	-	-	2.5	0.7	
		4.0	60	18.0	7.8	-	-	2.5	0.7	
KSZ 90/160B	2700 KW/cyl 3680 HP/cyl 8 cyl	2.5	85	10.9	8.8	-	-	1.5	0.3	
		4.0	85	17.5	8.8	-	-	1.5	0.3	
		2.5	60	11.0	8.9	-	-	1.4	0.3	
		4.0	60	17.7	8.9	-	-	1.4	0.3	
KSZ 90/160BL	2700 KW/cyl 3680 HP/cyl 8 cyl	2.5	85	11.1	8.8	-	-	1.6	0.2	
		4.0	85	17.7	8.8	-	-	1.6	0.2	
		2.5	60	11.2	8.9	-	-	1.4	0.3	
		4.0	60	17.9	8.9	-	-	1.4	0.3	

[a]Reference 10 (information originally provided in an Appendix to Reference 9).

AMERICAN MAN FOUR STROKE DIESEL ENGINE DATA
(Current Production as of March 1983)[a]

Fuel Type	Engine Classifcation	Rate Capacity KW/cyl	HC ppm	NO_x ppm	CO ppm	Load %	Exhaust Gas Mass[f] Kg/KW/hr	Fuel Consumption	
								L Engine g/KW/hr	V Engine g/KW/hr
Heavy Fuel[b]	L and V 20/27[c]	100	120	600	180	100	7.4	212	210
Heavy Fuel[b]	L and V 25/30[d]	220	300	1160	200	100	7.6	204	203
Heavy Fuel[b]	L and V 32/36[e]	370	120	760	300	100	8.4	198	195
Heavy Fuel[b]	L and V 40/45[e]	550	150	890	110	100	8.4	192	188
Heavy Fuel[b]	L and V 52/55[e]	775	290	1160	100	100	8.3	190	186

[a]Reference 10.
[b]Heating value (lower) = 42700 KJ/kg.
[c]L engine configuration consists of 4-9 cylinder engines.
V engine configuration consists of 12, 14, 16 and 18 cylinder engines.
[d]L engine configuration consists of 6, 8 and 9 cylinder engines.
V engine configuration consists of 12, 16 and 18 cylinder engines.
[e]L engine configuration consists of 6-9 cylinder engines.
[f]Exhaust gas density estimated to be 1.2240 kg/m^3 at 60°F an 1 atm. (std. conditions).
(This value obtained from measurement on a 14 cylinder V 52/55 engine is considered representative of exhaust densities from the engine classifications).

2. Fairbanks-Morse Diesel Engine Emission Data[a]

Reference 8

NOTE: These data were excluded from the data base due to a C rating which cannot be averaged with the A and B rated data

DIESEL ENGINE EXHAUST EMISSION DATA[a]

Fairbanks-Morse Engine Division

Below is listed the anticipated exhaust emissions with engines burning #2 diesel fuel.

Colt-Pielstick, 520 RPM, 650 HP/cylinder[b] (four stroke)		
NO_x	9.0	g/BHP/hr
CO	.8	g/BHP/hr
HC	.2	g/BHP/hr
SO_2	.9	g/BHP/hr
Particulates	.1	g/BHP/hr

Fairbanks-Morse 38TD8-1/8, 900 RPM, 320 HP/cylinder[c] (two stroke)		
NO_x	8.0	g/BHP/hr
CO	1.0	g/BHP/hr
HC	.3	g/BHP/hr
SO_2	1.0	g/BHP/hr
Particulates	.2	g/BHP/hr

Fairbanks-Morse 38D8-1/8, 900 RPM, 180 HP/cylinder[d] (two stroke)		
NO_x	17.0	g/BHP/hr
CO	.8	g/BHP/hr
HC	.3	g/BHP/hr
SO_2	1.1	g/BHP/hr
Particulates	.2	g/BHP/hr

[a]Data provided are average results over the engine classification range.
[b]This engine classification consists of 14, 16 and 18 cylinder engines.
[c]This engine classification consists of 6, 9, and 12 cylinder engines.
[d]This engine classification consists of 4, 5, 6, 8, 10, and 12 cylinder engines.

3. Caterpillar Tractor Company Industrial Diesel Engine (four stroke) Emission Data at Full Load (100%)

Reference 7

CATERPILLAR TRACTOR COMPANY INDUSTRIAL DIESEL ENGINE
(four stroke)
EMISSION DATA AT FULL LOAD (100%)

Sales Model	Rating at HP	Rating at RPM	100% gal/hr in fuel	g/hr Pollutant HC	CO	NO_x	SO_x	DPM[a]
D348	670	1800	35.1					
D348	850	2000	45.7	60	1000	5200	570	80
D379	500	1225	28.6					
D379	540	1300	31.3					
D379	550	1225	31.3	55	746	3601	404	55
D379	545	1225	31.2					
3304	140	1800	8.3	14	171	818	102	28
3304	165	2200	10.4	15	200	950	130	45
3304	125	2000	7.7	15	145	646	94	22
3304	90	2100		15	90	421	73	10
3304	100	2200	6.2	10	100	375	85	10
3304	85	2000	5.1	8	100	347	65	10
3306	195	2200		20	90	960	146	25
3306	270	2200	15.6	19	191	1208	196	17
3306	250	2200	13.7	15	80	1500	190	30
3306	150	2200		20	125	530	120	10
3306	180	2200		20	90	900	137	6
3306	198	1950		20	90	1290	150	25
3306	225	2200		16	82	1380	165	27
3306	165	2200		20	90	960	146	25
D348	900	2000		65	1100	5500	610	110
D398	825	1200	45.7	50	675	5980	600	43
D398	912	1200		50	730	6400	640	55
D379	570	1200		55	692	3694	412	54
D379	600	1200		55	758	3870	435	57
3208	120	2800		60	200	980	96	42
3208	130	2800		60	190	1070	102	38
D399	1215	1200		50	480	6100	850	160
3208	210	2800	11.5	10	1100	1370	150	175
3406	325	2100	17.4	70	460	2828	224	134
3406	285	2100		30	220	1683	209	32
3408	365	1800	19.9	60	550	2790	240	133
3408	475	2100	27.1	80	750	2447	317	170
3408	410	2100		40	620	3000	300	30
3408	450	2100		40	250	2279	330	83
3412	575	1800		60	680	3790	380	186

[a]DPM = dry particulate matter

4. Cummins Engine Company Diesel Engine Data

Reference 11

DIESEL ENGINE EMISSION DATA CUMMINS ENGINE COMPANY[a]

Emissions (g/HP/hr)	NO_x	HC	CO	Air (lb/hr)	Fuel Rate (lb/hr)
	Engine Model VT-255 (555 cu. in.) Rated HP 225 @ 3000 RPM				
100% Power	8.51	0.17	1.75	2415	92.7
75% Power	7.10	0.24	1.77	2203	70.5
50% Power	5.96	0.40	2.36	2061	53.8
25% Power	5.58	1.05	4.08	1861	36.5
2% Power	37.60	40.00	70.60	1770	21.5
	Engine Model VT-350 (903 cu. in.) Rated HP 340 @ 2400 RPM				
100% Power	9.74	0.21	1.58	3400	131
75% Power	7.04	0.27	0.89	3163	100
50% Power	5.20	0.47	1.06	2969	75
25% Power	3.82	1.14	2.13	2764	50
2% Power	12.29	29.70	38.00	2616	29
	Engine Model NTC-290 (855 cu. in.) Rated HP 290 @ 1900 RPM				
100% Power	11.50	0.14	0.99	2979	112.9
75% Power	9.51	0.14	0.73	2585	87.4
50% Power	7.63	0.22	0.91	2370	62.8
25% Power	5.77	0.43	1.33	2019	39.4
2% Power	30.90	5.02	24.60	1854	18.7
	Engine Model NTC-400 (855 cu. in.) Rated HP 400 @ 1900 RPM				
100% Power	10.70	0.20	1.00	3845	142.2
75% Power	9.23	0.17	0.58	3308	106.9
50% Power	7.57	0.21	0.57	2776	75.0
25% Power	6.42	0.43	0.86	2245	43.2
2% Power	37.30	28.10	20.20	1925	15.7

(Continued) DIESEL ENGINE EMISSION DATA CUMMINS ENGINE COMPANY[a]

Emissions (g/HP/hr)	NO_x	HC	CO	Air (lb/hr)	Fuel Rate (lb/hr)
	Engine Model KT-450 (1150 cu. in.) Rated HP 450 @ 2100 RPM				
100% Power	11.14	0.15	0.78	4357	171.2
75% Power	8.57	0.25	0.68	3885	132.9
50% Power	6.12	0.30	0.83	3395	96.7
25% Power	4.63	0.39	1.49	2949	62.1
2% Power	10.02	10.90	19.19	2538	31.8
	Engine Model KTA-600 Rated HP 600 @ 2100 RPM				
100% Power	11.62	0.14	0.79	5694	215.2
75% Power	9.19	0.14	0.36	5131	163.7
50% Power	6.73	0.21	0.42	4360	117.8
25% Power	5.31	0.33	0.60	3497	72.5
2% Power	2.94	8.34	7.36	2728	30.0

[a]The above emission data (Reference 4) are current (as of March 1983) EPA certification data of automotive diesel engines. Marine engines are not emission tested. The manufacturer, however, stated that these data "provide a close estimate of the emissions expected from marine engines".[11]

5. Detroit Diesel Allison Division of General Motors

Reference 12

ENGINE TYPE: 12V-149TI PROPULSION UNIT

COMPUTED DATA

Date: 3/22/74

RPM	Load %	BHP	BSFC (lb/BHP-hr)	F/C	PPM NO	PPM CO	BOSH	Air Flow CFM	Air Flow Mass	A/F	GM/HR NO	% NO	GM/HR CO	% CO
1900	100	1150	.397	183.3	1133	889	1.4	3903	266	34.9	8734	20	6397	32
1900	75	862	.401	138.9	1089	316	.7	3420	233	40.4	7334	17	1985	10
1900	50	575	.423	97.6	854	74	.4	3035	207	51.0	5077	12	409	2
1900	25	287	.533	61.4	478	42	.3	2687	183	71.8	2502	6	203	1
1900	2	0	186.1	27.0	134	126	.3	2297	159	142	605	1	533	3
1600	100	1018	.393	190.7	1042	1300	1.6	3175	216	32.4	6541	15	7610	38
1600	75	749	.382	136.6	1112	319	.7	2679	182	38.2	5866	14	1570	8
1600	50	509	.396	96.1	901	82	.4	2324	158	47.0	4102	9	349	2
1600	25	255	.494	60.0	507	73	.3	2084	142	67.6	2059	5	275	1
1600	2	0	157.2	22.8	106	150	.2	1858	128	160	383	1	508	3
650	0	0	95.5	13.9	89	165	.2	155	11	64	27	0	47	1

ENGINE TYPE: 8V-71T PRIME POWER GENERATOR SET

COMPUTED DATA

Date: 9/9/80

RPM	Load %	BHP	BSFC (lb/BHP-hr)	F/C	PPM NO	PPM CO	BOSH	Air Flow CFM	Air Flow Mass	A/F	GM/HR NO	% NO	GM/HR CO	% CO
1800	100	310	0.381	73.6	1220	702	0.3	82.8	1178	42.1	2918	22	1566	27
1800	75	232	0.389	56.3	1018	113	0.2	70.8	1008	47.1	2077	16	215	4
1800	50	155	0.420	40.6	696	102	0.2	61.9	880	57.0	1236	9	170	3
1800	25	77.0	0.519	24.9	386	92	0.1	57.2	814	85.9	630	5	140	2
1800	10	31.5	0.660	13.0	197	139	0.1	52.7	849	152	295	2	194	3
1500	100	269	0.380	76.5	1245	1561	0.9	62.5	889	36.7	2252	17	2635	45
1500	75	202	0.384	58.0	1150	225	0.6	56.2	799	43.4	1863	14	339	6
1500	50	135	0.405	40.9	757	113	0.4	49.1	699	53.9	1068	8	148	3
1500	25	67.0	0.483	24.2	396	137	0.1	44.2	629	81.9	500	4	162	3
1500	8	22.7	0.590	10.0	177	163	0.1	41.0	584	184	206	2	177	3

ENGINE TYPE: 8V-71TI PROPULSION UNIT

COMPUTED DATA

Date: 1/27/77

RPM	Load %	BHP	BSFC (lb/BHP-hr)	F/C	PPM NO	PPM CO	BOSH	Air Flow CFM	Air Flow Mass	A/F	GM/HR NO	% NO	GM/HR CO	% CO
2100	100	428	.392	90.1	1144	967	.6	88.8	1257	31.8	2955	23	2331	18
2100	75	321	.392	67.7	1070	209	.3	78.3	1108	37.4	2425	19	441	3
2100	50	214	.412	47.5	712	139	.2	70.8	1002	48.2	1451	11	265	2
2100	25	107	.508	29.2	396	150	.1	64.7	916	71.6	733	6	258	2
2100	2	25	1.21	16.4	285	205	.1	60.5	856	119	318	2	329	3
1500	100	310	.418	97.6	884	4758	2.3	57.9	819	26.8	1497	12	7513	58
1500	75	233	.388	67.9	1071	597	.7	49.6	702	33.0	1545	12	803	6
1500	50	155	.396	46.2	731	202	.2	46.0	652	45.1	970	8	250	2
1500	25	77	.468	26.9	460	225	.1	42.9	607	72.2	564	4	257	2
1500	2	23	.85	14.5	165	367	.2	41.5	588	130	195	2	404	3

ENGINE TYPE: 8V-71TI PROPULSION UNIT

COMPUTED DATA

Date: 1/26/77

RPM	Load %	BHP	BSFC (lb/BHP-hr)	F/C	PPM NO	PPM CO	BOSH	Air Flow CFM	Air Flow Mass	A/F	GM/HR NO	% NO	GM/HR CO	% CO
2300	100	451	.395	87.6	1160	512	.4	102	1447	34.4	3442	22	1418	16
2300	75	316	.404	63.1	970	173	.2	89.3	1263	42.0	2500	16	415	5
2300	50	226	.430	47.8	694	151	.2	81.9	1159	50.6	1633	11	332	4
2300	25	90	.608	27.0	326	148	.2	71.7	1014	78.3	666	4	283	3
2300	2	26	1.39	17.7	178	178	.2	68.4	968	114	347	2	322	4
1800	100	378	.394	93.4	1122	2241	1.0	72.1	1081	29.0	2360	15	4396	50
1800	75	284	.381	68.0	1047	296	.3	64.4	912	35.7	1954	13	516	6
1800	50	190	.397	47.2	730	161	.1	58.3	825	46.5	1227	8	252	3
1800	25	95	.473	28.1	434	182	.1	54.9	777	73.4	681	4	266	3
1800	2	21	1.11	14.6	261	280	.1	50.6	716	131	375	2	376	4

ENGINE TYPE: 8V-71T GENERATOR SET

COMPUTED DATA

Date: 11/1/76

RPM	Load %	BHP	BSFC (lb/BHP-hr)	F/C	PPM NO	PPM CO	BOSH	Air Flow CFM	Air Flow Mass	A/F	GM/HR NO	% NO	GM/HR CO	% CO
1800	100	408	.386	99.4	1653	892	.1	92.7	1320	35.4	4447	24	2238	20
1800	75	305	.384	74.0	1439	219	.1	80.2	1142	41.0	3334	18	474	4
1800	50	204	.399	51.4	967	123	.1	66.7	949	49.2	1856	10	221	2
1800	25	102	.477	30.7	517	134	.1	57.9	824	71.8	856	5	206	2
1800	2	14	1.59	14.4	194	158	.1	52.5	751	138	289	2	219	2
1500	100	340	.405	104.5	1254	3132	.4	72.4	1030	31.5	2642	14	6154	56
1500	75	254	.384	73.6	1367	414	.2	60.6	862	37.3	2399	13	677	6
1500	50	169	.392	50.2	986	156	.2	52.6	749	47.7	1494	8	220	2
1500	25	85	.456	29.2	561	156	.1	46.3	659	72.0	744	4	193	2
1500	2	9	1.74	12.0	188	224	.0	40.9	585	151	218	1	242	2

ENGINE TYPE: 12V-71T PRIME POWER GENERATOR SET

COMPUTED DATA

Date: 9/9/80

RPM	Load %	BHP	BSFC (lb/BHP-hr)	F/C	PPM NO	PPM CO	BOSH	Air Flow CFM	Air Flow Mass	A/F	GM/HR NO	% NO	GM/HR CO	% CO
1800	100	480	0.375	74.9	1342	720	0.3	119	1689	39.6	4606	23	2305	26
1800	75	360	0.368	57.0	958	101	0.2	107	1529	48.7	2962	15	291	3
1800	50	240	0.405	40.4	617	97	0.2	96.9	1379	59.8	1713	9	251	2
1800	25	120	0.510	25.4	297	93	0.1	87.8	1248	86.0	745	4	217	2
1800	4	20.3	0.650	13.0	187	95	0.1	79.0	1124	359	417	2	197	2
1500	100	420	0.372	78.0	1264	1596	0.9	96.9	1379	37.2	3546	18	4178	47
1500	75	315	0.371	58.3	1159	201	0.6	85.3	1214	43.8	2853	14	461	5
1500	50	210	0.386	40.5	796	152	0.4	74.8	1064	55.4	1709	9	305	3
1500	25	105	0.468	24.5	455	123	0.1	68.8	979	84.1	895	4	225	3
1500	3	12.0	0.595	10.0	246	168	0.1	61.5	874	516	428	2	272	3

ENGINE TYPE: 16V-71T PRIME POWER GENERATOR SET

COMPUTED DATA

Date: 9/9/80

RPM	Load %	BHP	BSFC (lb/BHP-hr)	F/C	PPM NO	PPM CO	BOSH	Air Flow CFM	Air Flow Mass	A/F	GM/HR NO	% NO	GM/HR CO	% CO
1800	100	600	0.381	71.3	1199	513	0.3	167	2378	43.9	5780	23	2306	24
1800	75	450	0.391	54.9	888	101	0.2	140	1997	47.9	3590	14	380	4
1800	50	300	0.424	39.7	577	97	0.2	123	1748	57.9	2032	8	318	3
1800	25	150	0.525	24.6	277	93	0.1	114	1618	86.7	900	4	281	3
1800	5	28.0	0.660	13.0	177	95	0.1	105	1498	342	526	2	263	3
1500	100	522	0.380	74.2	1303	1200	0.9	130	1848	39.3	4892	19	4204	44
1500	75	391	0.385	56.3	1160	201	0.6	110	1558	43.7	3664	14	592	6
1500	50	261	0.407	39.8	796	147	0.4	96.8	1378	54.7	2215	9	382	4
1500	25	130	0.487	23.7	455	123	0.1	87.0	1238	82.5	1131	4	285	3
1500	3	16.0	0.599	10.0	245	168	0.1	82.2	1169	514	570	2	363	4

6. Scott Environmental Technology Oil Tanker Emission Testing Data

Reference 9

Test Date	Fuel Type	Powerplant	Rated	DWT HP	Mode	Load %	SO_2 ppm	O_2 %	CO_2 %	HC ppm	NO_x ppm	CO ppm	Fuel Cons. gal/hr	Boiler Rating[d] MMBTU/hr
9/6/78	No. 6	Turbine (elec)	7,000	27,000	Offloading	26.7	562.6	8.8	9.3	3.1	304	1.0	294	-
10/4/78	No. 6	Steam Turbine	18,000	70,000	Offloading	41.7	747.8	5.25	12.7	2.3	188	63[b]	265-554	163.8
11/8/78	No. 6	Steam Turbine	18,000	70,000	Offloading	28.9	963	16.5	-	23	80	728	318	163.8
11/8/78	No. 6	Steam Turbine	18,000	70,000	Harbor Standby	14.9	-	14.9	-	21	83	699	164	163.8
11/8/78	No. 6	Steam Turbine	18,000	70,000	Harbor Standby	15.8	-	16.1	-	22	81	681	174	163.8
11/8/78	No. 6	Steam Turbine	18,000	70,000	Harbor Transit	37.5	-	13.5	-	15.1	115.4	491	413	163.8
11/8/78	No. 6	Steam Turbine	18,000	70,000	Sealane Trans.	59.9	-	6.6	-	3	227.5	96.8	660	163.8
11/9/78	No. 6	Steam Turbine	18,000	70,000	Full	102.6	809	4.4	-	1.4	227.5	156.6	1130	163.8
11/9/78	No. 6	Steam Turbine	18,000	70,000	Full	105.8	809	4.5	-	0.7	267.6	279	1164	163.8
11/9/78	No. 6	Steam Turbine	18,000	70,000	Full	100	809	4.5	-	1.1	260.6	337.2	1101	163.8
11/9/78	No. 6	Steam Turbine	18,000	70,000	Reduced Power	91.5	796	4.2	-	2.5	257.4	759.6	1007	163.8
11/9/78	No. 6	Steam Turbine	18,000	70,000	Reduced Power	89.6	796	5.3	-	0.9	253	65.7	986	163.8
11/9/78	No. 6	Steam Turbine	18,000	70,000	Sealane Trans.	74.6	-	7.9	-	3.5	214.4	114.5	821	163.8
11/10/78	No. 6	Steam Turbine	18,000	70,000	Transit	54.8	726	10.2	-	14.8	175.5	373.1	603	163.8
10/7/78	No. 6	Steam Turbine	26,000	120,000	Offloading	48.6	706.3	4.8	13.5	2.5	194	5.3	441-630[c]	-

Footnotes
[a]Reference 9.
[b]Instrument interference.
[c]Fuel consumption averaged used for calculation.
[d]Boiler ratings based on fuel value of 18,408 BTU/lb, fuel density of 8.1 lb/gal[19] and a rated boiler fuel consumption of 106.8 tons/day.

6. NO_x Monitoring of an Oil Tanker
Scott Environmental Technology

1. Data table was taken from Reference 17.

2. Testing was conducted on the British Renown Oil Tanker during offloading.

3. The tanker has two oil fired boilers that are designed for a max. evaporation of 141,000 lbs/hr.

4. Tests were conducted December 3, 1976.

7. NO_x Monitoring of an Oil Tanker
Scott Environmental Technology

1. Data table was taken from Reference 18.

2. Testing was conducted on the British Renown Oil Tanker during offloading.

3. The tanker has two oil fired boilers that are designed for a max. evaporation of 141,000 lbs/hr.

4. Tests were conducted December 3, 1976.

5. The NO_x concentrations (in ppm) are uncorrected.

TABLE 1

AVERAGE NO_x CONCENTRATIONS BY CHEMILUMINESCENCE ANALYZER

Time Begin	Time End	Minutes Data	Average ppm NO_x	Average NO_x lb/bbl.	Average % CO_2	Notes
1700	1730	15	231.5	3.21	7.6	Scott-Converter Bypass 1710-1715
1730	1830	30	240.5	3.33	7.6	
1830	1915	5	237	3.01	8.3	Scott-Instrument Drift and Filter Leak
1915	2000	30	248.5	3.15	8.3	
2000	2036	0	-	-	10.0	Scott-Instrument Drift and Filter Leak
2036	2100	18	254	2.68	10.0	Scott-Probe Span Chk. @ 2000
2100	2200	50	243	2.56	10.0	Ship-Blower Changes
2200	2232	26	232	2.55	9.6	
2232	2314	36	56	0.61	9.6	Ship-Air/Fuel Change in Boiler
2314	2400	42	183	2.01	9.6	
2400	0100	52	165.5	1.59	11.0	
0100	0200	54	191	1.83	11.0	
0200	0300	38	157	1.59	10.4	Ship-Changing Pumps/ Scott-Filter Change
0300	0405	34	71.68	0.73	10.4	Scott-Moisture in Lines Chg. Condenser
0405	0440	25	107	1.28	8.8	Ship-O_2 Alarm, Fans Shut Off @ 0440
0440	0500	18	202	2.42	8.8	
0500	0520	18	205	2.45	8.8	
0520	0600	30	122	1.46	8.8	Ship-Fans on @ 0520
0600	0636	32	139	1.44	10.2	Ship-Chg. Reading
0636	0700	24	229	2.37	10.2	
0700	0800	56	190	1.96	10.2	Ship-Chg. to 2 Pumps on Balast @ 0718
0800	0900	54	201	2.12	10.0	Scott-Conv. out 0810-0825
0900	1000	56	208.5	2.20	10.0	
1000	1100	57	214	2.15	10.5	
1100	1200	56	208	2.09	10.5	
1200	1300	42	211	2.12	10.5	Scott-Pen Malfunction, Converter bypass 1206-1240
1300	1400	56	246	2.47	10.5	
1400	1500	48	251	2.50	10.6	
1500	1600	58	296	2.94	10.6	
1600	1620	8	153	1.65	9.8	Ship-Concentration Dropping, Fans Off
1620	1700	40	69	0.74	9.8	
1700	1800	56	66	0.70	10.0	Ship-One Small Pump Operating
1800	1840	30	61	0.64	10.0	Scott-Instrument Sensitivity Increased
1840	1900	20	43	0.45	10.0	Ship-Hotelling Started 1840
1900	1920	16	45	0.55	8.7	
1920	1943	12	124	1.50	8.7	Ship-Fans Turned on @ 1920/Scott Probe Chk. 1940

TABLE 3. BOILER FIRING RATE, % CO_2 and O_2

Start	Stop	Firing Rate (bbl/2 Hour)	% CO_2	% O_2
1800	2000	89.0	8.3	--
2000	2200	87.7	10	7.0
2200	2400	88.4	9.6	7.3
2400	0200	86.5	11	6.2
0200	0400	75.1	10.4	6.1
0400	0600	73.5	8.8	6.2
0600	0800	75.9	10.2	6.4
0800	1000	74.4	10.0	7.5
1000	1200	78.5	10.5	7.5
1200	1400	77.1	10.5	7.0
1400	1600	76.2	10.6	6.4
1600	1700	43.8	9.8	6.2
1700	1900	30.0	10.0	6.5
1900	2000	27.0	8.7	7.5
*Stopped purging at 0630 - Took on ballast			8.24 Ave.	6.75 Ave.

Note: CO analysis was negligible at each of these sample times

TABLE 4

FUEL ANALYSIS

BRITISH RENOWN - NO_x STACK TEST

Ultimate Analysis

Carbon, %	84.40
Hydrogen, %	11.48
Nitrogen, %	0.29
Sulfur, %	2.56
Oxygen, %	0.40
Ash, %	0.03

Ash Analysis

	Minors(.1 .9 ppm)	Trace(<.1 ppm)
Na - 70 ppm	Zn = .7	Ag
V - 70 ppm	Pb - .4	Be
Ni - 8 ppm	Co - .4	Cd
Fe - 3 ppm	Ba - .3	Se
Ca - 2 ppm	Mn - .3	B
µg - 2	Cu - .2	
Si - 1	Mo - .2	
Al - 1	P - .15	
As - 1	Sn - .1	
	Ti - .1	
	W - .1	
	Cr - .1	

Physical Analysis

API gravity	15.9		
Pour, °F	30		
Flash P.M., °F	182		
Carbon, Residue, Ramsbottom	4.723		
B.S&W	0.8		
BTU content, BTU/#	18,450		
Viscosity, SUS @	100°F	130°F	210°F
	2200	673	110

Distillation

See page 15

8. Emission Testing Data for Fourteen U.S. Coast Guard Cutter Vessels [13 Diesel Engine Powered, One (USCG Campbell) Steam Powered]

Reference 13

Notes Per Vessel:

1. USCGC Vankton Tests Conducted 6/28, 6/29 and 7/8/72
2. USCGC Convslip Tests Conducted 7/10-7/12/72
3. USCGC Campbell - Data not used - % load unknown
4. USCGC Active Tests Conducted 8/3-8/4/72
5. USCGC Relief Test Conducted 8/8/72
6. USCGC 40538 Tests Conducted 8/11 and 8/14/72
7. USCGC White Heath Tests Conducted 8/16, 8/17, and 9/18/72
8. USCGC Chase Tests Conducted 8/23, 8/24 and 10/31/72
9. USCGC Spar Tests Conducted 8/29-8/31/72
10. USCGC Cape Horn Test Conducted 9/6/72
11. USCGC Point Jackson Tests Conducted 9/11-9/12/72
12. USCGC Shackle Tests Conducted 9/14-9/15/72
13. USCGC Decisive Tests Conducted 10/3-10/4/72
14. USCGC Boat 44318 Test Conducted 10/12/72

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 03/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 1
PAGE 1

VESSEL NAME : USCGC YANKTON — VESSEL REG # : 72
VESSEL TYPE & CLASS : WYTM - 110A

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT		
B1	BOILER	79230	WAY-WOLFF					#	
G1	STBD SS GENERATOR	6912	GENERAL MOTORS	GA-37165	18418	1825	52 KW	#	
G2	PORT SS GENERATOR	6911	GENERAL MOTORS	GA-37155	16557	3631	52 KW	#	
M1	STBD MAIN DIESEL ENG	TYPE S	INGERSOLL-RAND	44586	22815	5919	600 HP	#	720 RPM
M2	PORT MAIN DIESEL ENG	TYPE S	INGERSOLL-RAND	44587	22593	4991	600 HP	#	720 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL					# / HOUR				
							CO	THC	NOX	SOX	SMOKE	PART	CO	THC	NOX	SOX
G1	20 %	1160			12 KW		18.12		37.15		5.5					
G1	45 %	1160			24 KW		13.38		37.56		6.0					
G2	0 %	1240			0 KW		69.13	184.38	34.51		4.0					
G2	35 %	1230			18 KW		33.40	121.35	46.63		4.5					
G2	35 %	1230			17 KW		31.96	124.65	43.80		4.5					
G2	45 %	1230			23 KW		27.32	186.84	45.33		4.5					
M1	CRUISE	580	223				7.37	5.18	65.89		4.5					
M1	CRUISE	550	230				7.53	5.46	53.34		4.5					
M2	CRUISE	580	220				6.33	5.20	63.78		4.5					

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 03/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 2
PAGE 1

VESSEL NAME : USCGC COWSLIP — VESSEL REG # : 277
VESSEL TYPE & CLASS : WLB - 180A

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT		
B1	BOILER	FBM-46858HM1	VAPOR CLARKSON	12525	125000		600000 BTU	#	
G1	STBD SS GENERATOR	6-71	GENERAL MOTORS	6-71-146-958	80231	4388	190 HP	#	
G2	PORT SS GENERATOR	6-71	GENERAL MOTORS	6-71-146-935	78658	1320	190 HP	#	
M1	STBD MAIN DIESEL ENGINE	GND-8	COOPER-BESSEMER	1890	37679	2840	600 HP	#	600 RPM
M2	PORT MAIN DIESEL ENGINE	GND-8	COOPER-BESSEMER	1891	37683	2317	600 HP	#	600 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL					# / HOUR				
							CO	THC	NOX	SOX	SMOKE	PART	CO	THC	NOX	SOX
B1	NORMAL					43.2	3.62	1.85	2.25		6.5		.16	.85	.18	
G1	25 %	1200			18 KW	28.3	7.87	59.43	32.88		6.0		.16	1.21	.65	
G1	25 %	1200			18 KW	20.3	8.18	60.26	33.82		6.0		.17	1.23	.69	
G2	25 %	1200			14 KW	19.0	13.99	73.78	32.16		6.0		.27	1.41	.61	
G2	25 %	1200			16 KW	19.0	13.87	73.53	34.13		6.5		.26	1.40	.65	
G2	25 %	1200			28 KW	19.0	13.75	71.81	39.15		6.5		.26	1.37	.75	
G2	25 %	1230			20 KW	19.0	14.66	68.34	38.45		6.0		.29	1.38	.73	
M1	IDLE	320	0		0 HP		26.82	7.18	44.67							
M1	IDLE	320	0		0 HP		26.41	12.83	18.81							
M1	SLOW	480	178		282 HP	188.0	3.22	.54	58.58				.35	.06	5.46	
M1	SLOW	480	168		291 HP	188.0	2.91	1.44	54.36				.31	.16	5.87	
M1	SLOW	480	168		272 HP	188.0	2.94	1.58	55.83				.32	.17	5.94	
M1	CRUISE	520	288		472 HP	181.4	4.13	1.49	44.61		5.0		.75	.27	8.09	
M1	CRUISE	520	288		457 HP	181.4	3.58	2.18	41.41		5.0		.63	.40	7.51	
M1	CRUISE	520	192		443 HP	181.4	3.65	1.33	45.92				.66	.24	8.33	
M1	CRUISE	520	191		443 HP	181.4	3.54	1.33	45.92				.64	.24	8.33	
M1	CRUISE	530	196		443 HP	181.4	3.63	1.57	46.25				.62	.28	8.39	
M1	CRUISE	530	194		448 HP	181.4	3.48	1.57	45.76				.62	.28	8.30	
M2	IDLE	320	0		0 HP		28.86	8.48			4.0					
M2	IDLE	320	0		0 HP		23.19	9.76	44.52							
M2	SLOW	480	120		272 HP	116.2	3.22	1.34	60.53		5.0		.37	.23	7.04	
M2	CRUISE	520	192		472 HP	189.2	4.31	1.78	43.87				.81	.32	8.15	
M2	CRUISE	530	192		478 HP	189.2	3.83	1.76	44.81				.72	.33	8.48	
M2	CRUISE	530	194		469 HP	189.2	3.58	1.69	47.76				.68	.32	9.04	
M2	CRUISE	540	194		468 HP	189.2	3.64	1.67	49.28		5.5		.69	.32	9.31	
M2	CRUISE	540	194		468 HP	189.2	3.59	1.63	49.21				.68	.31	9.31	

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 03/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 3
PAGE 1

VESSEL NAME : USCGC CAMPBELL — VESSEL REG # : 32
VESSEL TYPE & CLASS : WHEC - 327

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSHOH HRS	RATED OUTPUT
M1	STBD MAIN ENG-SP E	FT4A-6	BABCOCK & WILCOX				1550 HP
M2	PORT MAIN ENG-SP A	FT4A-6	BABCOCK & WILCOX				1550 HP
M3	STBD MAIN ENG-SP F	FT4A-6	BABCOCK & WILCOX				1550 HP
M4	PORT MAIN ENG-SP B	FT4A-6	BABCOCK & WILCOX				1550 HP
M5	STBD MAIN ENG-SP G	FT4A-6	BABCOCK & WILCOX				1550 HP
M6	PORT MAIN ENG-SP C	FT4A-6	BABCOCK & WILCOX				1550 HP
M7	STBD MAIN ENG-SP H	FT4A-6	BABCOCK & WILCOX				1550 HP
M8	PORT MAIN ENG-SP D	FT4A-6	BABCOCK & WILCOX				1550 HP

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL				SMOKE	# / HOUR				
							CO	THC	NOX	SOX		PART	CO	THC	NOX	SOX
M1	IDLE		0			604.4	.41		5.62		1.0		.25		3.48	
M1	CRUISE		180			1205.9	.43	.14	4.87		2.5		.52	.17	5.87	
M1	FULL		220			2112.2	1.79	.17	4.88		2.5		3.79	.37	10.30	
M2	IDLE		0			604.4	1.28		6.32		2.5		.78		3.82	
M2	CRUISE		180			1411.9	.41	.09	5.41		3.5		.58	.13	7.64	
M2	FULL		220			2112.2	.36	.03	5.59		3.0		.76	.07	11.82	
M3	IDLE		0			604.4	.47		5.45		1.0		.28		3.29	
M3	CRUISE		180			1205.9	.38	.10	5.15		3.0		.46	.12	6.22	
M3	FULL		220			2112.2	2.08	.11	4.34		2.5		4.40	.23	10.22	
M4	IDLE		0			604.4	1.79		5.13		1.0		1.08		3.10	
M4	CRUISE		180			1411.9	.43	.05	5.28	25.80	5.0		.61	.07	7.46	36.42
M4	FULL		220			2112.2	.80	1.31	5.79		1.5		1.69	2.76	12.23	
M5	IDLE		0			604.4	.78		5.61		1.5		.47		3.39	
M5	CRUISE		190			1205.9	.29	.09	5.90	36.12	3.5		.34	.11	7.12	43.56
M5	FULL		220			2112.2	1.39	.02	4.87	27.42	2.0		2.31	.05	10.29	57.92
M6	IDLE		0			604.4	1.93		6.18		2.0		1.17		3.73	
M6	CRUISE		180			1411.9	.44	.10	5.27		5.0		.61	.14	7.44	
M6	FULL		220			2112.2	.31	.04	5.42	28.13	2.0		.65	.08	11.46	59.42
M7	IDLE		0			604.4	.65		5.37		2.0		.39		3.25	
M7	CRUISE		180			1205.9	.28	.06	5.48				.33	.07	6.51	
M7	FULL		220			2112.2	1.84	.11	5.07		3.0		2.19	.23	10.71	
M8	IDLE		0			604.4	6.42		5.89		2.5		3.88		3.88	
M8	CRUISE		180			1411.9	1.81	.11	4.26		4.5		1.43	.16	5.74	
M8	FULL		220			2112.2	.34	.04	5.23		2.0		.73	.07	11.06	

AVERAGE EMISSION RATES

	MODE	FUEL RATE #/HR	# / 1000 # FUEL				# / HOUR				
			CO	THC	NO_x	SO_x	PART	CO	THC	NO_x	SO_x
STARBOARD BOILER	IDLE	604.4	.58	-	5.51	-		.35	-	3.33	-
	CRUISE	1205.9	.34	.094	5.36	37.64	3.283	.44	.11	6.46	45.39
	FULL	2112.2	1.49	.101	4.92	29.02	17.121	3.15	.21	10.39	61.29
PORT BOILER	IDLE	604.4	2.85	-	5.68			1.72	-	3.43	
	CRUISE	1411.9	.38	.088	4.98	24.65	3.690	.32	.12	7.03	34.80
	FULL	2112.2	.45	.35	5.50	29.67	14.720	.95	.74	11.62	62.67

NOTES: CRUISE AND FULL VALUES ARE STACK VELOCITY WEIGHTED AVERAGES.
IDLE VALUES ARE AREA WEIGHTED AVERAGES.

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 03/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 4 — PAGE 1

VESSEL NAME : USCGC ACTIVE — VESSEL REG # : 618
VESSEL TYPE & CLASS : WMEC - 210A

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT	
B1	STBD BOILER	R81650-S	VAPOR	1784	21888			B
B2	PORT BOILER	R81650-S	VAPOR	1783	21888			B
G1	STBD SS GENERATOR	D343TA	CATERPILLAR	339639	11133		288 KW	B
G2	PORT SS GENERATOR	D343TA	CATERPILLAR	339638	18556		288 KW	B
M1	STBD MAIN DIESEL-FWD SP	FV8M-12-T	COOPER-BESSEMER	6865	7668		1588 HP	B
M2	PORT MAIN DIESEL-FWD SP	FV8M-12-T	COOPER-BESSEMER	6864	7656		1588 HP	B
M3	STBD MAIN DIESEL-STRN SP	FV8M-12-T	COOPER-BESSEMER	6865	7668		1588 HP	B
M4	PORT MAIN DIESEL-STRN SP	FV8M-12-T	COOPER-BESSEMER	6864	7656		1588 HP	B

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL CO	THC	NOX	SOX	SMOKE	# / HOUR PART	CO	THC	NOX	SOX
B2	NORMAL						9.81	43.82	1.59		6.8					
B2	LO FLM						9.72	33.59	1.56		6.8					
G1	0 %	1800			0 KW		12.16	.86	23.56		7.8					
G1	40 %	1800			80 KW		4.83	1.95	22.96		9.8					
G1	63 %	1800			125 KW		13.75	2.91	16.55		9.5					
G2	0 %	1800			0 KW		17.23	4.52	19.63		6.8					
G2	30 %	1800			60 KW		7.99	2.87	21.88		8.8					
G2	55 %	1800			110 KW		6.12	2.72	16.46		7.8					
M1	SLOW	530	160	.2			19.85		51.49		4.5					
M1	CRUISE	600	185	.8			6.26		87.88			1.188				
M1	FULL	890	265	.8			38.98	2.67			8.8	3.616				
M2	FULL	900	265	.8			35.93	1.87	63.18							
M3	SLOW	530	160	.2			19.32		52.81		4.5					
M3	CRUISE	600	185	.8			6.27		87.23		5.8					
M3	FULL	890	265	.8			31.79	3.19	73.54							
M4	FULL	900	265	.8			35.74	1.86	62.15		9.5					

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 03/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 5 — PAGE 1

VESSEL NAME : USCGC RELIEF — VESSEL REG # : 613
VESSEL TYPE & CLASS : WLV - 128

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT	
B1	STBD BOILER	N-193	YORK-SHIPLEY		11239		350000 BTU	B
B2	PORT BOILER	N-193	YORK-SHIPLEY		13557		350000 BTU	B
G1	STBD SS GENERATOR	48648	GENERAL MOTORS	6A-18552	64885	4294	48 KW	B
G2	PORT SS GENERATOR	48648	GENERAL MOTORS	6A-18554	56543	3847	48 KW	B
M1	MAIN DIESEL ENG	2488-8	GENERAL MOTORS				668 HP	B

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL CO	THC	NOX	SOX	SMOKE	# / HOUR PART	CO	THC	NOX	SOX
B2	NORMAL					25.2	2.29		8.48		1.8		.86		.21	
G1	0 %	1200			0 KW		22.78	68.86	33.53		5.8					
G1	50 %	1200			19 KW		9.72	38.33	33.23		6.8					
G1	75 %	1200			30 KW		8.37	28.82	35.32		7.8					
G2	0 %	1200			0 KW		18.16	93.85	25.77		6.8					
G2	50 %	1200			23 KW		9.97	39.89	32.12							
G2	50 %	1200			16 KW		9.64	42.60	29.67		6.5					
G2	75 %	1200			27 KW		9.88	36.25	38.43							
G2	75 %	1200			34 KW		10.24	34.45	33.18		7.5					

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 83/85/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 6
PAGE 1

VESSEL NAME : USCGC 40538 — VESSEL REG # : 40538
VESSEL TYPE & CLASS : WYT - 40

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT
M1	STBD MAIN DIESEL ENG	6072-A-AM	GENERAL MOTORS	6A-17521	2243		280 HP @ 2000 RPM
M2	PORT MAIN DIESEL ENG	6071-A-LM	GENERAL MOTORS	6A-198616	2246		280 HP @ 2000 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL					# / HOUR				
							CO	THC	NOX	SOX	SMOKE	PART	CO	THC	NOX	SOX
M1	IDLE	650	0			1.4	73.85	53.91			5.5		.11	.08		
M1	CRUISE	800	400			17.3	17.89	29.74			3.0		.30	.51		
M1	FULL	1000	500			33.6	18.26	18.69			1.0		.34	.63		
M2	SLOW	600	300			8.2	39.73	28.66			7.0		.33	.17		
M2	SLOW	600	300			8.2	28.80	16.25	52.27				.24	.13	.43	
M2	CRUISE	800	400			17.3	18.63	28.71			5.0		.32	.36		
M2	CRUISE	800	400			17.3	18.17	15.99	59.39				.31	.28	1.03	
M2	FULL	1000	500			34.6	8.33	16.01			4.0		.29	.55		
M2	FULL	1000	500			34.6	9.74	13.44	59.94				.34	.46	2.07	

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 83/85/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 7
PAGE 1

VESSEL NAME : USCGC WHITE HEATH — VESSEL REG # : 545
VESSEL TYPE & CLASS : WLM - 133

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT
B1	BOILER	BS-8	BUCKLEY & SCOTT	19356			65000 BTU @
G1	FWD SS GENERATOR	M-18878	CUMMINS	875189	1884	1884	60 KW @ 1500 RPM
G2	AFT SS GENERATOR	6DTG-317	BUDA	156765	3798	3798	30 KW @ 1450 RPM
M1	STBD MAIN DIESEL ENG	36	UNION	43566	35868	3275	300 HP @ 350 RPM
M2	PORT MAIN DIESEL ENG	36	UNION	43565	35868	2821	300 HP @ 350 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL					# / HOUR				
							CO	THC	NOX	SOX	SMOKE	PART	CO	THC	NOX	SOX
B1	NORMAL					18.0	.84	2.29	1.96		5.0		.32	.84	.84	
G1	99 %	1500			60 KW	31.7	39.14	22.89	18.91		9.5		1.24	.73	.35	
M1	SLOW	120	120			13.0	8.29	7.96	47.48		6.0		.11	.10	.61	
M1	CRUISE	200	200			43.2	7.68	8.45	53.86		5.5		.33	.36	2.33	
M1	FULL	310	310			110.9	6.11	1.98	36.28		7.0		.68	.21	4.02	
M1	FULL	320	320				11.68	3.24	38.83		9.5					
M2	CRUISE	260	260			37.4	5.68	5.12	55.49		5.0		.21	.19	2.08	
M2	FULL	330	330			92.2	6.59	2.71	45.98		6.0		.61	.25	4.23	
M2	FULL	340	340			99.4	8.47	3.91	42.34		7.0		.84	.39	4.21	

SCOTT RESEARCH LABORATORIES SRL 1382-816-8373 DATE 03/09/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS VESSEL # : 8
PAGE 1

VESSEL NAME : USCGC CHASE VESSEL REG # : 718
VESSEL TYPE & CLASS : WHEC - 378

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT	
B1	STBD BOILER	RO-118-CG	VAPOR CORP	18843	16888		0	
B2	PORT BOILER	RO-118-CG	VAPOR CORP	18842	16888		0	
G1	STBD SS GENERATOR	8-567EZ	GENERAL MOTORS	67-81-1897	15688	1888	588 KW	0
G2	PORT SS GENERATOR	8-567EZ	GENERAL MOTORS	67-81-1122	14888	1888	588 KW	0
M1	STBD MAIN DIESEL ENG	38TD-8-1/2	FAIRBANKS-MORSE	97883	6643	0	3688 HP	0 900 RPM
M2	PORT MAIN DIESEL ENG	38TD-8-1/2	FAIRBANKS-MORSE	97882	7388	5588	3688 HP	0 900 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL				SMOKE	# / HOUR				
							CO	THC	NOX	SOX		PART	CO	THC	NOX	SOX
B1	NORMAL					234.7	4.86	1.87	2.59		4.8		.95	.44	.61	
B1	LO FLM					215.3	3.49	.95	3.83		4.8		.75	.28	.65	
B2	NORMAL					234.7	2.45	2.52	2.48		4.8		.57	.59	.56	
B2	LO FLM					215.3	2.32	2.74	2.25		4.5		.58	.59	.48	
G1	0 %	750			0 KW	61.7	5.89	35.87	28.75		7.8		.36	2.16	1.28	
G1	80 %	750			480 KW	283.9					7.4	.932				
G1	80 %	750			480 KW	283.9	13.83	9.85	56.87		6.5	.932	2.66	1.85	11.43	
G1	80 %	750			435 KW		17.54	6.95	62.72		5.8	.932				
G1	90 %	750			450 KW	255.3	21.17	5.84	64.73		7.8		5.41	1.49	16.52	
G2	0 %	740			0 KW	51.8	18.68	23.64	21.61		6.8		.58	1.23	1.12	
G2	50 %	740			230 KW	142.4	5.54	18.32	31.34		7.8		.79	1.47	4.46	
G2	80 %	740			380 KW	227.5	7.26	6.75			7.5		1.65	1.54		
M1	SLOW	468	76	.5		192.2	21.86	9.18	56.52		1.8		4.28	1.77	10.86	
M1	2/3	560	94	1.1		443.5	4.93	3.88	49.74		2.8		2.19	1.69	22.06	
M1	CRUISE	742	123	1.1		768.2	5.34	3.58	43.36		5.8		3.87	2.75	33.31	
M1	FULL	828	135	1.1		1856.2	9.78	3.48	41.55		9.8	5.832	18.33	3.67	43.39	
M1	FULL	848	135	1.0		1856.2	9.66	3.88	40.42		6.0	5.832	18.28	4.18	42.69	
M2	COLD	0	0	.98			23.59		66.45							
M2	SLOW	458	78	.5		192.2	19.87	7.78	46.57		1.5	1.921	3.82	1.58	8.95	
M2	2/3	558	95	1		407.5	2.95	3.35	51.88		6.8		1.28	1.37	20.78	
M2	CRUISE	688	188	1		779.8	18.22	4.45	54.25		3.5	3.288	7.96	3.47	42.26	
M2	CRUISE	728	125	.98		779.8	2.93	8.77	49.88		6.8		2.28	7.29	38.88	
M2	FULL	888	148	.98		1183.8	6.87	5.86	47.48		7.5	11.244	7.58	5.58	52.28	
M2	FLANK	848	158	.98		1319.8	11.44	4.23	48.88		9.8		15.89	5.59	63.32	

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 83/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 9 — PAGE 1

VESSEL NAME : USCGC SPAR — VESSEL REG # : 483
VESSEL TYPE & CLASS : WLB - 180C

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOM HRS	RATED OUTPUT
B1	STBD BOILER	FBM-66858	VAPOR	12183	448		600000 BTU @
B2	PORT BOILER	FBM-66858	VAPOR	12184	60		600000 BTU @
G1	STBD SS GENERATOR	6-DTG-844	BUDA	84339	4414	4414	63 KW @ 1200 RPM
G2	PORT SS GENERATOR	6-DTG-844	BUDA	26423	62339	4181	63 KW @ 1200 RPM
M1	STBD MAIN DIESEL ENG	GN-8	COOPER-BESSEMER	2826	76616	2855	700 HP @ 700 RPM
M2	PORT MAIN DIESEL ENG	GN-8	COOPER-BESSEMER	2825	72983	747	700 HP @ 700 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL CO	THC	NOX	SOX	SMOKE	# / HOUR PART	CO	THC	NOX	SOX
G1	20 %	1250			11 KW		24.68	25.48	18.38		7.5					
G2	20 %	1350			15 KW		20.39	14.93	22.59		7.0					
M1	IDLE	320	0				36.46	12.78	37.99		2.0					
M1	CRUISE	595	180				4.40	1.08	63.90		5.0					
M1	CRUISE	510	185				2.80	1.21	64.34		5.0					
M2	IDLE	320	0				45.89	14.14	31.89		1.5					
M2	CRUISE	680	190				12.28	1.58			7.0	.179				
M2	CRUISE	680	190				5.19	1.13	59.33		6.0	.179				
M2	CRUISE	515	184				2.22	1.38	68.46		5.5					

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 83/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 10 — PAGE 1

VESSEL NAME : USCGC CAPE HORN — VESSEL REG # : 95322
VESSEL TYPE & CLASS : WPB - 95C

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOM HRS	RATED OUTPUT
B1	BOILER	3638-18E	WAY-WOLFF				@
G1	FWD SS GENERATOR	2-71	GENERAL MOTORS	242-3885	15335	4890	20 KW @
G2	AFT SS GENERATOR	2-71	GENERAL MOTORS	242-3628	14279	5210	20 KW @
M1	FWD STBD MAIN DIESEL	VT12M	CUMMINS	231336	3478	3478	600 HP @ 2100 RPM
M2	FWD PORT MAIN DIESEL	VT12M	CUMMINS	231339	18765	18765	600 HP @ 2100 RPM
M3	AFT STBD MAIN DIESEL	VT12M	CUMMINS	231337	16822	7718	600 HP @ 2100 RPM
M4	AFT PORT MAIN DIESEL	VT12M	CUMMINS	231338	18968	7717	600 HP @ 2100 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL CO	THC	NOX	SOX	SMOKE	# / HOUR PART	CO	THC	NOX	SOX
G1	60 %	1250			12 KW		3.22	31.27	59.86		6.0					
G2	0 %	900			0 KW		16.92	41.36	43.59		6.0					
G2	50 %	1250			10 KW		5.98	36.21	55.81		5.5					
M1	SLOW	1140	400				7.77	1.83	25.82		7.5					
M1	CRUISE	1600	550				7.67	6.03	48.82		7.5					
M2	SLOW	1200	400				9.80	2.95	25.17		8.0					
M2	CRUISE	1650	550				22.69	1.65	47.88		8.5					
M3	SLOW	1190	400				15.22	4.38	25.48		6.5					
M3	CRUISE	1690	550				19.01		54.83		7.5					
M4	SLOW	1180	400				9.81	2.82	22.44		8.0					
M4	CRUISE	1730	550				17.66	3.89	16.85		9.0	.382				
M4	CRUISE	1680	550				15.88	.67	44.31		8.5	.382				

SCOTT RESEARCH LABORATORIES SRL 1382-816-8373 DATE 83/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS VESSEL # : 11
PAGE 1

VESSEL NAME : USCGC POINT JACKSON VESSEL REG # : 82378
VESSEL TYPE & CLASS : WPB - 820

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT
B1	BOILER	W-120	REPCO	288-7			230000 BTU @
G1	FWD SS GENERATOR	2-71	GENERAL MOTORS	2A77878	1162		20 KW @
G2	AFT SS GENERATOR	2-71	GENERAL MOTORS	2A78216	844		20 KW @
M1	STBD MAIN DIESEL - FSP	VT-12-900M	CUMMINS	679763-3	1248		900 HP @ 2300 RPM
M2	PORT MAIN DIESEL - FSP	VT-12-900M	CUMMINS	681361-3	1238		900 HP @ 2300 RPM
M3	STBD MAIN DIESEL - ASP	VT-12-900M	CUMMINS	679763-3	1248		900 HP @ 2300 RPM
M4	PORT MAIN DIESEL - ASP	VT-12-900M	CUMMINS	681361-3	1238		900 HP @ 2300 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL					# / HOUR				
							CO	THC	NOX	SOX	SMOKE	PART	CO	THC	NOX	SOX
B1	NORMAL					16.6	.45	.24	2.82		3.5		.81	.38	.83	
G1	0 %	1250			0 KW	4.3	13.67	8.76	52.68		2.3		.86	.34	.23	
G1	30 %	1250			6 KW	5.8	5.99	7.88	65.49		2.5		.83	.35	.38	
G1	80 %	1250			17 KW	10.8	2.66	4.83	65.97		5.3		.83	.35	.71	
G2	0 %.	1250			0 KW	2.9	14.58	23.88	89.17		2.5		.34	.37	.26	
G2	30 %	1250			7 KW	4.3	5.86	13.18	52.65		3.3		.83	.36	.36	
G2	70 %	1250			14 KW	8.6	4.34	6.78	77.18		4.3		.84	.36	.67	
M1	IDLE	650	0				12.46	27.76	16.99		6.3					
M1	2/3	1350	430				9.84	3.84	26.83		8.3					
M1	CRUISE	1900	640			224.6	12.36	3.71	65.48		9.3		2.71	.83	14.69	
M2	IDLE	680	0				58.37	42.19	13.22		5.5					
M2	2/3	1380	420				8.93	.88	23.22		8.5					
M2	CRUISE	2300	630			224.6	11.99	1.89	48.31		9.3		2.69	.24	10.85	
M3	2/3	1350	430				7.84		26.91		8.3					
M3	CRUISE	1900	620			229.3	18.61		49.23		7.5		2.43		11.27	
M4	2/3	1350	420				9.25		19.77		8.5					
M4	CRUISE	2300	620			229.3	18.79		39.18		9.3		2.47		8.97	

SCOTT RESEARCH LABORATORIES SRL 1382-816-8373 DATE 83/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS VESSEL # : 12
PAGE 1

VESSEL NAME : USCGC SHACKLE VESSEL REG # : 65689
VESSEL TYPE & CLASS : WYTL - 65B

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSMOH HRS	RATED OUTPUT
B1	BOILER	1924-BC	WAY-WOLFF	2288			185000 BTU @
G1	FWD SS GENERATOR	2-71	GENERAL MOTORS	2AS2539	3526		20 KW @
G2	AFT SS GENERATOR	2-71	GENERAL MOTORS	2AS2548	1994		20 KW @
M1	MAIN DIESEL ENGINE	6LBDCSM	WAUKESHA	28918	5183		500 HP @ 1200 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL					# / HOUR				
							CO	THC	NOX	SOX	SMOKE	PART	CO	THC	NOX	SOX
B1	NORMAL						13.78	3.83	2.25		1.5					
G1	0 %	900			0 KW		28.24	37.69	77.21		4.8					
G1	50 %	1320			10 KW		9.88	53.96	54.98		4.5					
G2	0 %	900			0 KW		33.39	33.84	62.98		5.3					
G2	35 %	1320			7 KW		18.81	58.18	48.11		5.5					
G2	40 %	1320			9 KW		18.37	53.75	45.72		5.5					
M1	IDLE	550	0			15.8	39.67	16.58	13.96				.63	.26	.22	
M1	CRUISE	850	295				14.81	6.25	47.56		4.5					
M1	FULL	1200	412			146.9	11.83	3.28	37.81				1.74	.47	5.55	

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 83/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 13
PAGE 1

VESSEL NAME : USCGC DECISIVE — VESSEL REG # : 629
VESSEL TYPE & CLASS : WMEC - 2108

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSHOH HRS	RATED OUTPUT
B1	STBD BOILER	RB 1650-CG	VAPOR				@
B2	PORT BOILER	RB 1650-CG	VAPOR	18288	3446		@
G1	STBD SS GEN-MAN SP	D343TA	CATERPILLER	3381547	7111		200 KW @ 1800 RPM
G2	PORT SS GEN-MAN SP	D343TA	CATERPILLER	3381554	9929	187	200 KW @ 1800 RPM
G3	STBD SS GEN-JNCT SP	D343TA	CATERPILLER	3381547	7111		200 KW @ 1800 RPM
G4	PORT SS GEN-JNCT SP	D343TA	CATERPILLER	3381554	9928	187	200 KW @ 1800 RPM
M1	STBD MAIN DIESEL-MAN SP	16-251-B	ALCO	9386	9814		2500 HP @ 1200 RPM
M2	PORT MAIN DIESEL-MAN SP	16-251-B	ALCO	9384	7771		2500 HP @ 1200 RPM
M3	STBD MAIN DIESEL-JNCT SP	16-251-B	ALCO	9386	9814		2500 HP @ 1200 RPM
M4	PORT MAIN DIESEL-JNCT SP	16-251-B	ALCO	9384	7771		2500 HP @ 1200 RPM
M5	STBD MAIN DIESEL-STHN SP	16-251-B	ALCO	9386	9814		2500 HP @ 1200 RPM
M6	PORT MAIN DIESEL-STHN SP	16-251-B	ALCO	9384	7771		2500 HP @ 1200 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL CO	THC	NOX	SOX	SMOKE	# / HOUR PART	CO	THC	NOX	SOX
B2	NORMAL					46.8	68.34	1.98	2.48		7.5		2.82	.89	.11	
B2	LO FLM					32.4	9.99	2.87	1.97		3.3		.32	.89	.26	
G1	@ %	1750			0 KW	19.8	26.64	13.52	17.13		6.3		.51	.26	.33	
G1	73 %	1750			145 KW	78.7	9.84	4.13	27.13		8.3		.77	.33	1.58	
G4	85 %	1750			170 KW	162.8	2.34	.37	13.47		7.5		.38	.06	3.15	
M2	SLOW	500	160	53		73.4	9.13	5.37	66.48		9.3		.67	.37	4.89	
M2	2/3	660	204	85		345.6	18.18	2.16	53.28		9.3		6.25	.75	17.35	
M2	CRUISE	920	275	85		1885.5	9.88	1.78	54.67		6.3		9.89	1.71	54.97	
M2	FULL	990	298	85		1886.6	10.97	1.97	53.52		6.3		11.45	1.98	56.89	
M3	SLOW	525	160	64		127.9	8.37	3.32	45.18		5.5		1.07	.42	5.98	
M3	2/3	640	195	85		285.1	15.92	3.25	41.44		8.5		4.54	.93	11.82	
M3	FULL	1300	388	84		1389.2	19.31	3.48	53.73		6.5		19.49	3.51	53.22	
M5	SLOW	525	160	64		127.9	8.22	1.92	44.94				1.05	.25	5.75	
M5	2/3	660	203	84		285.1	15.21	2.09	42.67				4.34	.59	12.17	
M5	FULL	1300	388	84		1389.2	18.87	3.77	53.05				18.97	3.81	58.39	
M6	SLOW	500	160	53		73.4	8.23	2.34	73.15				.68	.17	5.74	
M6	2/3	660	208	85		345.6	21.88	1.75	43.99		9.5		7.56	.61	16.93	
M6	CRUISE	950	278	86		1885.5	11.68	2.36	59.82		6.5		11.46	2.38	55.32	
M6	FULL	990	298	85		1886.6	12.78	2.74	57.16		7.3		12.78	2.76	57.53	

SCOTT RESEARCH LABORATORIES — SRL 1382-816-8373 — DATE 83/05/73
BASELINE STACK EMISSION DATA - COAST GUARD VESSELS — VESSEL # : 14
PAGE 1

VESSEL NAME : USCGC BOAT 44318 — VESSEL REG # : 44318
VESSEL TYPE & CLASS : WLB - 44

POWERPLANT DESCRIPTION DATA FOR SAMPLED VESSEL :

CODE	POWERPLANT DESCRIPTION	ENG.MODEL	ENG. MFGR.	SERIAL #	TOT.ENG. TIME-HRS	TSHOH HRS	RATED OUTPUT
M1	STBD MAIN DIESEL ENG	V6-280M	CUMMINS	337642	2368		280 HP @ 3300 RPM
M2	PORT MAIN DIESEL ENG	V6-280M	CUMMINS	362982	387		280 HP @ 3300 RPM

EXHAUST EMISSION DATA ON A MASS BASIS :

ENG	MODE	ENG RPM	SHAFT RPM	PROP PITCH	APPROX. LOAD	FUEL RATE #/HR	# / 1000 # FUEL CO	THC	NOX	SOX	SMOKE	# / HOUR PART	CO	THC	NOX	SOX
M1	IDLE	740					18.87	51.08	.83		8.3					
M1	SLOW	1535					15.68	17.27	18.26		8.3					
M1	FULL	2600					49.83	2.13	38.15		9.5					
M2	IDLE	740					7.71	59.84	.97		5.5					
M2	SLOW	1500					11.98	7.82	14.83		7.3					
M2	FULL	2250					13.13	3.87	25.72		9.5					
M2	FULL	2250					18.83	3.38	29.82		9.5					

9. U.S. Coast Guard Abatement Program Boat Diesel Engines

Reference 17

U.S. COAST GUARD BOAT DIESEL ENGINES[a]

MASS EMISSION DATA

A. Engine Model 607, Serial No. 6A60137

					Dry Concentrations Corrected to Wet							Mass Emission							
												lb/hr				g/bhp/hr			
Date	Time	Mode	hp	rpm	Correc. Factor	CO (ppm)	CO_2 (%)	O_2 (%)	NO (ppm)	NO_2 (ppm)	THC (ppm)	CO	NO	NO_2	THC	CO	NO	NO_2	THC
3/20	0920	1	idle	700	.9855	1123	0.99	18.72	360	47	770	1.72	.092	.013	.590	-	-	-	-
3/20	0940	2	20	1200	.9803	490	1.62	18.92	181	59	4--	0.97	.624	.011	.476	22.0	14.1	.250	10.8
3/20	1005	2	18	1200	.9803	451	1.62	19.02	188	55	4--	0.898	.617	.011	.438	22.6	15.56	.277	11.0
3/20	1035	3	70	1380	.9654	251	3.28	16.51	459	24	590	.567	1.703	.002	.666	3.67	11.04	.13	4.32
3/20	1105	3	71	1380	.9654	241	3.28	15.93	465	22	440	.547	1.736	.002	.499	3.49	11.1	.13	3.19
3/20	1142	4	102-105	1600	.9659	249	4.21	14.64	603	14	430	.5-5	2.373	.001	.574	2.60	10.5	.004	2.84
3/20	1220	4	101-103	1600	.9607	231	3.79	14.65	610	12	470	.611	2.66	.001	.623	2.72	11.8	.004	2.77
3/20	1245	5	150-152	1800	.9522	857	4.67	13.09	747	0	380	2.55	3.66	0	.566	7.67	11.01	0	1.70
3/20	1310	5	150	1800	.9506	780	4.85	13.07	746	0	260	2.25	3.53	0	.375	6.79	10.7	0	1.135
3/20	1330	6	182	1800	.9439	982	5.57	11.52	755	0	250	3.72	4.71	0	.474	9.29	11.7	0	1.18

B. Engine Model 6071, Serial No. 6A60144

					Dry Concentrations Corrected to Wet							Mass Emission							
												lb/hr				g/bhp/hr			
Date	Time	Mode	hp	rpm	Correc. Factor	CO (ppm)	CO_2 (%)	O_2 (%)	NO (ppm)	NO_2 (ppm)	THC (ppm)	CO	NO	NO_2	THC	CO	NO	NO_2	THC
3/2/73	0855	1	67.5	1400	.9655	241	3.28	14.82	570	19	1600	.626	2.429	.002	2.074	4.2	16.33	.013	13.45
3/2/73	0930	1	72	1425	.9655	232	3.28	14.72	570	19	1600	.601	2.430	.002	2.074	3.78	15.32	.012	13.07
3/2/73	0955	2	20	1200	.9800	451	1.67	16.90	235	61	1100	1.71	1.460	.011	2.088	38.8	33.3	.249	7.4
3/2/73	1005	3	110	1600	.9587	201	4.03	13.66	757	10	1250	.573	3.548	.001	1.780	2.36	14.64	.004	7.35
3/2/73	1042	3	108	1600	.9592	201	3.98	13.76	763	10	1200	.581	3.616	.001	1.730	2.44	15.2	.004	7.27
3/2/73	1050	4	140	1780	.9449	350	3.53	12.14	850	0	1300	.937	3.751	0	1.743	3.04	12.16	.0	5.65
3/2/73	1130	4	135	1770	.9458	303	5.44	12.06	870	0	1150	.828	3.918	0	1,574	2.78	13.17	.0	5.29
3/2/73	1133	5	185	1975	.9427	1018	5.75	10.74	909	0	120	3.536	5.197	0	2.084	8.67	12.75	.0	5.11

[a]Reference 17.

U.S. COAST GUARD BOAT DIESEL ENGINES[a]

MASS EMISSION DATA

C. Engine Model 6072A, Serial No. 6A20533

Date	Time	Mode	hp	rpm	Dry Concentrations Corrected to Wet							Mass Emission							
												lb/hr				g/bhp/hr			
					Correc. Factor	CO (ppm)	CO_2 (%)	O_2 (%)	NO (ppm)	NO_2 (ppm)	THC (ppm)	CO	NO	NO_2	THC	CO	NO	NO_2	THC
3/7/73	0840	1	22.5	1200	.9778	401	1.91	16.87	293	68	1100	.837	1.008	0.011	1.148	16.8	20.3	.22	23.16
3/7/73	0908	1	21.0	1200	.9783	372	1.86	17.85	274	68	980	.800	0.970	0.011	1.055	17.29	20.97	.24	22.81
3/7/73	0926	2	67.5	1390	.9646	232	3.38	15.55	531	34	1350	.578	2.180	.003	1.686	3.88	14.65	0.20	11.34
3/7/73	1005	2	67.5	1390	.9646	233	3.38	15.92	559	29	800	.592	2.335	.003	1.015	3.98	15.82	0.20	6.82
3/7/73	1120	3	107	1600	.9593	232	3.93	14.39	696	14	950	.627	3.091	.001	1.283	2.66	13.1	.004	5.44
3/7/73	1143	3	105	1610	.9587	232	4.03	14.38	705	12	750	.616	3.075	.001	0.995	2.66	13.29	.004	4.30
3/7/73	1215	4	142.5	1790	.9508	666	4.85	12.84	332	0	820	2.148	4.417	.000	1.323	6.84	14.08	0	4.21
3/7/73	1240	4	142.5	1790	.9501	608	4.94	13.06	827	0	820	1.929	4.314	.000	1.301	6.14	13.7	0	4.14
3/7/73	1315	5	185	2000	.9407	1072	5.93	11.05	790	0	780	4.548	5.513	.000	1.654	11.16	13.5	0	4.05

[a]Reference 17.

10. Multi-Cylinder Diesel Engine Tests Water in Fuel Emulsions

Zero Percent Water Emission Data

Reference 16

MULTI-CYLINDER DIESEL ENGINE TESTS[a]
CUMMINS ENGINE EMISSION DATA[b]

Rated Horsepower: 800
Rated Speed: 2300 RPM
Measured at 1800 rpm
Fuel Type: Diesel fuel with 35.3° API at 60°F
0% Water Emulsion

Run #	BHP	Fuel Flow (lb/hr)	HC		CO		NO_x	
			(g/BHP/hr)	(g/hr)	(g/BHP/hr)	(g/hr)	(g/BHP/hr)	(g/hr)
171	436	182	0.28	122	1.62	705	8.09	3,527
177	442	177	0.11	50	0.87	385	8.58	3,789
183	444	181	0.35	155	3.22	1,431	8.38	3,720
188	416	55	0.23	27	1.75	203	4.61	536
195	436	179	0.21	82	1.41	615	7.73	3,371
201	434	180	0.19	81	2.78	1,206	7.70	3,339
216	444	177	0.21	95	0.62	275	6.64	2,950
217	436	180	0.16	72	1.25	547	6.76	2,949
223	441	179	0.14	63	1.25	551	5.63	2,483
231	443	180	0.14	60	1.25	562	5.85	2,588
237	449	181	0.15	69	1.27	608	6.34	2,842
245	445	182	0.24	107	1.35	539	5.22	2,322
251	447	182	0.08	34	6.34	632	5.30	2,373

[a]Reference 16.
[b]Cummins Engine Company, Inc. Model VTA-1710-C800 (VT12-900M).
Type: Four Stroke Cycle, Bore and Stroke: 5.5 x 6, No. of Cylinders: 12, Displacement: 1710 cu. in., Rated Horsepower: 800 at prop shaft Rated Speed: 2300 RPM.

MULTI-CYLINDER DIESEL ENGINE TESTS[a]
DETROIT DIESEL ENGINE[b]

600 RPM, rated 1800
Rated HP: 1200
Fuel Type: Diesel fuel with 35.1° API - 7.07 lb/gal

Run #	BHP	Fuel Flow (lb/hr)	HC		CO		NO_x	
			(g/BHP/hr)	(g/hr)	(g/BHP/hr)	(g/hr)	(g/BHP/hr)	(g/hr)
142	45	24.1	7.06	310	5.91	260	21.6	951
Same Fuel at 800 rpm - Same Engine								
114	92	43.0	4.30	388	2.21	199	17.61	1588
120	94	43.3	3.95	356	2.24	202	17.09	1541
Same Engine and Fuel at 1000 rpm								
107	172	73.3	2.92	488	1.08	180	15.05	2513
113	174	73.4	3.56	594	1.30	217	14.48	2418
Same Engine and Fuel at 1200 rpm								
121	289	115	2.65	746	0.83	234	13.06	3673
127	294	116	2.68	755	0.85	239	12.60	3542
144	290	115	2.92	822	0.83	233	12.72	3577
150	295	116	2.77	779	0.87	246	12.51	3519
Same Engine and Fuel at 1400 rpm								
123	453	178	2.22	977	1.45	640	13.47	5940
134	459	178	2.60	1147	1.39	613	13.10	5776

[a]Reference 16.

[b]General Motors Corporation, Detroit Diesel Allison Division
Model: 12V-149TI (16V-149TI), Type: Two stroke cycle, Bore and Stroke: 5.75 x 5.75, No. of Cylinder: 12 (16), Displacement: 1788 cu. in., Rated Horsepower: 900 (1200), Rated Speed: 1800 rpm.

11. Land-based Steam Generation Systems Naval Ship and Research Center

Reference 21

NOTES:

1. Navy Distillate Fuel (ND) Heating Value = 19,300 BTU/lb
   Navy Special Fuel Oil (NSFO) Heating Value = 18,700 BTU/lb

2. A density of 8.1 lb/gal (NSFO) and 7.12 lb/gal (ND) was used to convert emission results to the units used in the data base.

TABLE 3
POLLUTION DATA, NAVY DISTILLATE FUEL
CLEAR STACK, OPTIMUM EXCESS AIR

Operating Conditions			Pollution Measurements			
Run No.	% Full Power	Burners	Sulfur Dioxide[1] lb/10^6 Btu		Oxides of Nitrogen[2] lb/10^6 Btu	
			A	B	C	D
1	100	6	0.93	0.09[3]	-	0.36
6	100	4	-	-	-	-
7	100	5	-	-	-	-
9	100	6	1.06	1.11	-	0.32
19	100	6	1.03	0.98	0.29	0.30
14	35	6	0.99	0.73	0.21	0.17
16	35	6	1.00	0.98	0.16	0.15
3	11	3	0.83	0.31[3]	-	0.18
12	11	3	0.87	-	0.15	0.17
15	11	3	0.91	0.85	0.15	0.15
Mean Value[4,5]			0.95	0.93		

[1] A - Dynascience Corp., SS 330 Electrochemical.
B - Manual Wet Chemical Method 6 of Federal Register, 23 Dec 1971.

[2] C - Dynascience Corp., NX 220 Electrochemical.
D - Manual Wet Chemical ~~Method 7~~ of Federal Register, 23 Dec 1971.

[3] Values discarded in determining mean value

[4] Mean represents constant output independent of all other conditions.

[5] Theoretical SO_2 emission calculated from sulfur content of fuel (1.02%) and HHV (19,300 Btu/lb) is 1.06 lb/10^6 Btu.

TABLE 4
POLLUTION DATA, NAVY DISTILLATE FUEL
NONCLEAR STACK, LOW AND HIGH EXCESS AIR

Operating Conditions					Pollution Measurements			
Run No.	% Full Power	Burners	Stack Conditions	Excess Air	Sulfur Dioxide[1] lb/10^6 Btu		Oxides of Nitrogen[2] lb/10^6 Btu	
					A	B	C	D
2	100	6	Heavy Trace	Low	0.74	-	0.29	-
11	100	6	Black+	Low	1.11	1.27	-	0.20
20	100	6	Heavy Trace	Low	1.20	-	0.34	0.27
17	35	6	Heavy Trace	Low	0.97	-	0.19	0.13
13	35	6	White	High	0.66	-	-	0.21
18	35	6	White	High	0.52	-	1.15	-
4	11	3	Heavy Trace	Low	0.75	0.29	-	0.16
Mean[3, 4]					0.85			

[1] A - Dynascience Corp., SS 330 Electrochemical.
B - Manual Wet Chemical Method 6 of Federal Register, 23 Dec 1971.

[2] C - Dynascience Corp., NX 220 Electrochemical.
D - Manual Wet Chemical Method 7 of Federal Register, 23 Dec 1971.

[3] Mean represents constant output independent of all other conditions.

[4] Theoretical SO_2 emission calculated from sulfur content of fuel (1.02%) and HHV (19,300 Btu/lb) is 1.06 lb/10^6 Btu.

TABLE 5

POLLUTION DATA, NAVY SPECIAL FUEL OIL
VARIOUS STACK CONDITIONS AND EXCESS AIR

Operating Conditions					Pollution Measurements			
Run No.	% Full Power	Burners	Stack Conditions	Excess Sir	Sulfur Dioxide[1] lb/10^6 Btu		Oxides of Nitrogen[2] lb/10^6 Btu	
					A	B	C	D
21	10	3	Light Trace	Optimum	1.20	0.94	0.25	0.26
22	10	3	White	High	0.74	0.79	1.25	0.22
23	10	3	Heavy Trace	Low	1.44	1.40	0.32	0.45
24	35	6	Light Trace	Optimum	1.82	-	0.42	0.62
25	100	6	Light Trace	Optimum	2.02	-	0.57	0.69
26	100	6	Heavy Trace	Low	2.03	-	0.54	0.67
			Mean[3,4]		1.54			

[1] A - Dynascience Corp., SS 330 Electrochemical.
B - Manual Wet Chemical Method 6 of Federal Register, 23 23 Dec 1971.
[2] C - Dynascience Corp., NX 220 Electrochemical.
D - Manual Analytical Method, Method 7, Federal Register, 23 Dec 1971.
[3] Mean value for SO_2 reflects constant output (independent of all other conditions).
[4] Theoretical SO_2 emission calculated from sulfur content of fuel (1.67%) and HHV (18,700 Btu/lb) is 1.78 lb/10 Btu.

TABLE 6

POLLUTION EMISSIONS OF NAVAL DISTILLATE
VERSUS NAVY SPECIAL FUEL OIL AT THREE
DIFFERENT POWER RATES

% Full Power	SO_2 Emission lb/10^6 Btu		NO_x Emission lb/10^6 Btu	
	ND	NSFO	ND	NSFO
100	0.74-1.20	2.02-2.03	0.29-34	0.54-0.57
35	0.52-1.00	1.82	0.16-1.15	0.42
11	0.75-0.91	0.74-1.44	0.15	0.25-1.25

TABLE 7

PARTICULATE DATA
NAVY DISTILLATE AND NAVY SPECIAL FUEL OIL

Operating Conditions				Pollution Measurements		
Run No.	% Full Power	Burners	Fuel	Particulate Mass Conc Lb /hr	Particulate Mass Conc Lb /10^6 Btu	% Isokinectic
3	11	3	ND	30.8971	1.1523	61.9
4	11	3	ND	53.4502	1.9935	60.5
12	11	3	ND	13.8812	0.5177	63.9
15	11	3	ND	3.1983	0.1193	66.6
21	11	3	NSFO	16.0067	0.6103	62.4
16	35	6	ND	11.2350	0.1372	61.1
24	35	6	NSFO	23.6635	0.2924	65.4
1	100	6	ND	120.2089	0.4635	69.0
9	100	6	ND	206.8551	0.7976	65.7
19	100	6	ND	18.8910	0.0728	-
25	100	6	NSFO	279.2463	1.4340	59.2

Conc - concentration

12. Shipboard Testing of Boiler Stacks Naval Ship Research and Development Center Emission Data

Reference 22

Note: Only particulate data from the two naval vessels were used in the data base. The referenced document indicated that the other pollutant measurements were invalid.

USS KAWISHIWI - NDFO EMISSION DATA	OPERATING PARAMETER		
	HOTELING (20% Load)	10 KNOTS (40% Load)	17 KNOTS (90-100%)
Fuel Burning Rate (gal/min)	3.2	5.5	16.6
Fuel Burning Rate (BTU/hr)	26.9×10^6	46.2×10^6	139.4×10^6
Particular Matter (grains/scf)	.0108	.0241	.0104
(#/scf)	1.54×10^{-6}	1.57×10^{-6}	1.49×10^{-6}
(#/hr)	1.75	2.27	4.09
(#/10^6BTU)	.065	.049	.029
SO_2 (ppm)	40	–	–
SO_2 (#/10^6BTU)	–	–	–
NO_x (ppm)	20	–	–
NO_2 (#/10^6BTU)	–	–	–
CO (ppm)	250	250	250
CO_2 (%)	6	1 1/2	3.0
O_2 (%)	16.5	15 1/2	12.5
Excess Air Based on % O_2	–	–	–

USS JUNEAU - NDFO EMISSION DATA	OPERATING PARAMETER	
	50% Load[2]	100% Load[3]
Fuel Burning Rate (gal/min)	8.75	11.65
Fuel Burning Rate (BTU/hr)	$73.46/10^6$	109.98×10^6
Particular Matter (grains/scf)	0.1538	0.0353
(lb/scf)	22.02×10^{-6}	5.05×10^{-6}
(lb/hr)	27.48	11.65
(lb/10^6BTU)	0.374[1]	0.108
SO_2 (ppm)	550	500
SO_2 (lb/10^6BTU)	1.55[1]	4.16[1]
NO_x (ppm)	50	–[4]
NO_2 (lb/10^6BTU)	0.067	–[4]
CO (ppm)	140	112
CO_2 (%)	11.4	8.5
O_2 (%)	4.0	5.0
Excess Air Based on % O_2	22	28

NOTES: EPA Limits, Reference (d)
Particular Matter - 0.20 lb/10^6BTU
SO_2 - 0.80 lb/10^6BTU
NO_2 - 0.30 lb/10^6BTU

(1) Exceeds EPA limit
(2) 3 burners @ 245 divisions (burner adjustment)
(3) 5 burners @ 275 divisions (burner adjustment)
(4) NO_x sensor malfunction (no readings obtained)

13. Shipboard Steam Generator Systems Naval Ship Research and Development Center U.S.S. Forrest Sherman Emission Data

Reference 23

Note: Emission tests aboard the U.S.S. Sherman were conducted September 17-19, 1980

A low sulfur fuel (0.57% by wt sulfur) with a heating value of 19,515 BTU/lb was the fuel used during testing of a 1200 psi steam generator aboard the U.S.S. Sherman

SOURCE EMISSION DATA FROM USS FORREST SHERMAN (DD 931)

Run No.*	Time	Smoke RN	Particulates lb/MBtu	SO_2			NO_x		HC ppm	CO ppm	O_2 %	EA %	CO_2 %	Dry ft^3/lb fuel
				Measured		Theoretical ppm	ppm	lb/MBtu						
				ppm	lb/MBtu									
1	1600	0.25	0.036	163	0.49	195	116	0.25	12.5	24.1	10.33	90.9	8.13	352
2	1800	0.25	0.028	153	0.46	193	115	0.25	8.9	20.3	10.39	92.6	8.35	355
3	1920	0.35	0.016	140	0.42	196	112	0.24	6.9	7.0	10.29	90.0	8.02	350
4	0850	0.25	0.039	179	0.62	167	85	0.21	4.2	18.5	11.90	121.2	6.46	410
5	1000	0.35	0.040	132	0.45	171	94	0.23	6.5	13.4	11.76	116.7	6.13	401

*Runs 1-3 at hoteling rate;
runs 4 & 5 at harbor transit rate.

14. Results from Emission Testing Aboard the Submarine Tender U.S.S. L. Y. Spear - Testing Performed on a 600 psi Main Propulsion Boiler

Reference 19

TABLE 3
NAVY DISTILLATE FUEL

Element Analysis	% by Weight[1]	
	A	B
Carbon	85.7	85.8
Hydrogen	13.6	13.4
Sulfur	0.41	0.48
Nitrogen	0.1	0.1
HHV, Btu/lb	19,630.0	19,590.0

[1]Two samples taken during testing period.

TABLE 6
POLLUTION DATA USS L. Y. SPEAR (AS 36)
ND FUEL

Power Condition %	No. of Burners	Excess Air %	Smoke RN	Particulate (No./10^6 Btu)	Sulfur Dioxide	Oxides of Nitrogen
27	1	81	0.41	0.05(1)	0.33	0.09
27	1	93	0.50	0.065(2)	0.33	0.06
57	3	55	0.72	0.035	0.38	0.25
100	3	60	0.63	0.034	0.46	0.20

(1) Average of three runs using lo-vol particulate sampler. Tests were performed pierside in Norfolk, Virginia, during period 29 April-3 May 1974.
(2) Single run using hi-vol particulate sampler. Test was performed at pierside in Halifax, Nova Scotia, during sea trials of 24 June-3 July 1974.

TABLE 10
CARBON MONOXIDE AND HYDROCARBON EMISSIONS

Power Condition %	Carbon Monoxide p/m	Hydrocarbons as p/m Methane
27	64	16
57	20	<100
100	0	<100

15. Improved Marine Boiler Reliability Study

Emission Data

Reference 2

TABLE 1

SUMMARY OF BOILER DESIGN PARAMETERS

Condition		Full Power	Overload
Rating	%	100	115
Total Evaporation	lb/hr	108,000	124, 200
Pressure at Superheater Outlet	psig	870	870
Temperature at Superheater Outlet	°F	955	955
Food Temperature	°F	286	286
Efficiency	%	88.5	88.2
Oil Firing Rate	lb/hr	7669	8852
Air Temperature to Burners	°F	291	291
Excess Air	%	10	10
Furnace Release Rate	Btu/hr-ft^3	86,600	100,000
Absorption Rate RHAS	Btu/hr-ft^2	67,400	75,000
Firing Rate/RHAS	lb oil/hr-ft^2	9.1	10.5
Heat Input	Btu/hr	148 x 10^6	170 x 10^6

TABLE 6-1

TEST DATA AND RESULTS FOR CONDITION #1

11% BOILER RATING WITH 192% EXCESS AIR

Test Date					10/26/76		
Actual Boiler Load, % of Full Power					11	(In-Port)	
Excess Air, %					192	(Clear Stack)	
Sample Number		8	9	10	11	12	Avg.
O_2 % By Volume		14.0	14.0	14.0	14.0	14.0	14.0
CO	PPM	575	575	575	575	575	
NO_x	PPM	80	80	80	80	80	
SO_2	PPM	766	696	684	749	731	
SO_3	PPM	13.6	12.1	10.2	10.9	13.9	
CO - PPM Adj. To 3% O_2		1479	1479	1479	1479	1479	1479
NO_x - PPM Adj. To 3% O_2		206	206	206	206	206	206
SO_2 - PPM Adj. To 3% O_2		1970	1790	1758	1926	1880	1865
SO_3 - PPM Adj. To 3% O_2		35	31.1	26.2	28.0	35.7	31.2
% Conversion of SO_2 to SO_3		1.74	1.71	1.47	1.43	1.86	1.64

Note: The above excess air value results from the minimum inlet vane damper leakage with the forced draft fan on low speed and the inlet vanes closed down to the mechanical stops.

TABLE 6-2

TEST DATA AND RESULTS FOR CONDITION #2

27% BOILER RATING WITH 40% EXCESS AIR

Test Date					10/29/76	
Actual Boiler Load, % of Full Power					27	
Excess Air, %					40	(Clear Stack)
Sample Number		40	41	42	Avg	
O_2 % By Volume		6.0	6.1	6.5	6.2	
CO	PPM	5	0	0		
NO_x	PPM	160	160	160		
SO_2	PPM	1629	1667	1663		
SO_3	PPM	18.0	18.9	19.0		
CO - PPM Adj. To 3% O_2		6	0	0	2	
NO_x - PPM Adj. To 3% O_2		192	193	199	195	
SO_2 - PPM Adj. To 3% O_2		1955	2014	2064	2011	
SO_3 - PPM Adj. To 3% O_2		21.6	22.8	23.6	22.7	
% Conversion of SO_2 to SO_3		1.09	1.12	1.13	1.11	

TABLE 6-3

TEST DATA AND RESULTS FOR CONDITION #3

29% BOILER RATING WITH 88% EXCESS AIR

Test Date 10/29/76

Actual Boiler Load, % of Full Power 29

Excess Air, % 98 (Clear Stack)

Sample Number		43	44	45	Avg
O_2 % By Volume		11.0	10.5	10.4	10.6
CO	PPM	0	0	0	
NO_x	PPM	101	100	100	
SO_2	PPM	1101	1205	1190	
SO_3	PPM	19.7	21.0	26.8	
CO - PPM Adj. To 3% O_2		0	0	0	0
NO_x- PPM Adj. To 3% O_2		182	171	170	174
SO_2- PPM Adj. To 3% O_2		1982	2066	2021	2023
SO_3- PPM Adj. To 3% O_2		35.1	36.0	45.5	38.9
% Conversion of SO_2 to SO_3		1.74	1.71	2.20	1.88

TABLE 6-4

TEST DATA AND RESULTS FOR CONDITION #4

44% BOILER RATING WITH 17% EXCESS AIR

Test Date 10/29/76

Actual Boiler Load, % of Full Power 44

Excess Air, % 17 (Clear Stack)

Sample Number		38	39	Avg
O_2 % By Volume		3.1	3.1	3.1
CO	PPM	15	10	
NO_x	PPM	185	185	
SO_2	PPM	1925	1928	
SO_3	PPM	20.2	20.8	
CO - PPM Adj. To 3% O_2		15	10	13
NO_x- PPM Adj. To 3% O_2		186	186	186
SO_2- PPM Adj. To 3% O_2		1936	1939	1937
SO_3- PPM Adj. To 3% O_2		20.3	20.9	20.6
% Conversion of SO_2 to SO_3		1.04	1.07	1.06

TABLE 6-5

TEST DATA AND RESULTS FOR CONDITION #5

46% BOILER RATING WITH 24% EXCESS AIR

Test Date 10/29/76

Actual Boiler Load, % of Full Power 46

Excess Air, % 24 (Clear Stack)

Sample Number		34	35	37	Avg
O_2 % By Volume		3.9	4.3	4.0	4.1
CO	PPM	7	2	0	
NO_x	PPM	190	186	185	
SO_2	PPM	1939	1869	1879	
SO_3	PPM	18.7	18.8	19.4	
CO - PPM Adj. To 3% O_2		7	2	0	3
NO_x- PPM Adj. To 3% O_2		200	200	196	199
SO_2- PPM Adj. To 3% O_2		2041	2014	1990	2015
SO_3- PPM Adj. To 3% O_2		19.7	20.3	20.5	20.2
% Conversion of SO_2 to SO_3		.96	1.00	1.02	.99

TABLE 6-6

TEST DATA AND RESULTS FOR CONDITION #6

44% BOILER RATING WITH 33% EXCESS AIR

Test Date 10/29/76

Actual Boiler Load, % of Full Power 44

Excess Air, % 33 (Clear Stack)

Sample Number		36
O_2 % By Volume		5.4
CO	PPM	0
NO_x	PPM	180
SO_2	PPM	1700
SO_3	PPM	20.1
CO - PPM Adj. To 3% O_2		0
NO_x- PPM Adj. To 3% O_2		207
SO_2- PPM Adj. To 3% O_2		1962
SO_3- PPM Adj. To 3% O_2		23.2
% Conversion of SO_2 to SO_3		1.17

TABLE 6-7

TEST DATA AND RESULTS FOR CONDITION #7

79% BOILER RATING WITH 10% EXCESS AIR

Test Date 10/28/76

Actual Boiler Load, % of Full Power 79

Excess Air, % 10 (Clear Stack)

Sample Number		28	29	30	Avg
O_2 % By Volume		1.85	2.0	2.0	1.95
CO	PPM	140	40	60	
NO_x	PPM	201	201	200	
SO_2	PPM	2264	2225	2184	
SO_3	PPM	20.6	18.9	20.3	
CO - PPM Adj. To 3% O_2		132	38	57	76
NO_x- PPM Adj. To 3% O_2		189	190	190	190
SO_2- PPM Adj. To 3% O_2		2128	2108	2069	2102
SO_3- PPM Adj. To 3% O_2		19.4	17.9	19.2	18.8
% Conversion of SO_2 to SO_3		.90	.84	.92	.89

TABLE 6-8

TEST DATA AND RESULTS FOR CONDITION #8

78% BOILER RATING WITH 16% EXCESS AIR

Test Date 10/29/76

Actual Boiler Load, % of Full Power 78

Excess Air, % 16 (Clear Stack)

Sample Number		31	32	33	Avg.
O_2 % By Volume		2.9	3.0	3.0	3.0
CO	PPM	0	0	0	
NO_x	PPM	220	220	220	
SO_2	PPM	2029	2037	2053	
SO_3	PPM	20.8	19.2	20.0	
CO - PPM Adj. To 3% O_2		0	0	0	0
NO_x- PPM Adj. To 3% O_2		219	220	220	220
SO_2- PPM Adj. To 3% O_2		2018	2037	2053	2036
SO_3- PPM Adj. To 3% O_2		20.7	19.2	20.0	20.0
% Conversion of SO_2 to SO_3		1.02	.93	.96	.97

TABLE 6-9

TEST DATA AND RESULTS FOR CONDITION #9

95% BOILER RATING WITH 5% EXCESS AIR

Test Date: 10/27/76

Actual Boiler Load, % of Full Power: 95

Excess Air, %: 5 (Clear Stack)

Sample Number		13	14	15	Avg.
O_2 % By Volume		1.1	1.1	1.1	1.1
CO	PPM	350	350	350	
NO_x	PPM	240	240	240	
SO_2	PPM	2392	2429	2459	
SO_3	PPM	10.5	13.4	10.6	
CO - PPM Adj. To 3% O_2		316	316	316	316
NO_x - PPM Adj. To 3% O_2		217	217	217	217
SO_2 - PPM Adj. To 3% O_2		2164	2197	2224	2195
SO_3 - PPM Adj. To 3% O_2		9.5	12.1	9.6	10.4
% Conversion of SO_2 to SO_3		.43	.54	.43	.47

TABLE 6-10

TEST DATA AND RESULTS FOR CONDITION #10

95% BOILER RATING WITH 9% EXCESS AIR

Test Date: 10/25/76

Actual Boiler Load, % of Full Power: 95

Excess Air, %: 9 (Clear Stack)

Sample Number		5	6	7	Avg.
O_2 % By Volume		1.8	1.8	1.8	1.8
CO	PPM	305	305	305	
NO_x	PPM	233	233	233	
SO_2	PPM	2318	2347	2356	
SO_3	PPM	19.6	14.4	12.5	
CO - PPM Adj. To 3% O_2		286	286	286	286
NO_x - PPM Adj. To 3% O_2		218	218	218	218
SO_2 - PPM Adj. To 3% O_2		2173	2200	2209	2194
SO_3 - PPM Adj. To 3% O_2		18.4	13.5	11.7	14.5
% Conversion of SO_2 to SO_3		.84	.61	.53	.66

TABLE 6-11

TEST DATA AND RESULTS FOR CONDITION #11

94% BOILER RATING WITH 16% EXCESS AIR

Test Date 10/25/76

Actual Boiler Load, % of Full Power 94

Excess Air, % 16 (Clear Stack)

Sample Number	1	2	3	4	Avg.
O_2 % By Volume	3.0	3.0	3.0	3.0	3.0
CO PPM	15	15	15	15	
NO_x PPM	250	250	250	250	
SO_2 PPM	2018	2157	2059	2209	
SO_3 PPM	19.6	14.7	14.3	13.9	
CO - PPM Adj. To 3% O_2	15	15	15	15	15
NO_x- PPM Adj. To 3% O_2	250	250	250	250	250
SO_2- PPM Adj. To 3% O_2	2018	2157	2059	2209	2110
SO_3- PPM Adj. To 3% O_2	19.6	14.7	14.3	13.9	13.6
% Conversion of SO_2 to SO_3	.96	.68	.69	.63	.74

TABLE 6-12

TEST DATA AND RESULTS FOR CONDITION #12

94% BOILER RATING WITH 22% EXCESS AIR

Test Date 10/27/76

Actual Boiler Load, % of Full Power 94

Excess Air, % 22 (Clear Stack)

Sample Number	16	17	18	Avg.
O_2 % By Volume	4.1	4.1	4.1	4.1
CO PPM	0	0	0	
NO_x PPM	265	265	265	
SO_2 PPM	2030	1977	1984	
SO_3 PPM	24.1	21.5	26.2	
CO - PPM Adj. To 3% O_2	0	0	0	
NO_x- PPM Adj. To 3% O_2	282	282	282	282
SO_2- PPM Adj. To 3% O_2	2162	210	2113	2127
SO_3- PPM Adj. To 3% O_2	25.7	29.9	27.9	27.8
% Conversion of SO_2 to SO_3	1.17	1.40	1.30	1.29

TABLE 6-14

TEST DATA AND RESULTS FOR CONDITION #14

110% BOILER RATING WITH 9% EXCESS AIR

Test Date		10/28/76		
Actual Boiler Load, % of Full Power		110		
Excess Air, %		9 (Clear Stack)		
Sample Number	22	23	24	Avg.
O_2 - % By Volume	1.95	1.90	1.80	1.85
CO PPM	10	40	40	
NO_x PPM	269	265	265	
SO_2 PPM	2226	2234	2259	
SO_3 PPM	25.5	20.8	23.6	
CO - PPM Adj. To 3% O_2	10	37	37	38
NO_x - PPM Adj. To 3% O_2	254	248	248	250
SO_2 - PPM Adj. To 3% O_2	2103	2094	2118	2105
SO_3 - PPM Adj. To 3% O_2	24.1	19.5	22.1	21.9
% Conversion of SO_2 to SO_3	1.13	.92	1.03	1.03

TABLE 6-13

TEST DATA AND RESULTS FOR CONDITION #13

111% BOILER RATING WITH 5% EXCESS AIR

Test Date		10/28/76		
Actual Boiler Load, % of Full Power		111		
Excess Air, %		5 (Very Hazy Stack)		
Sample Number	25	26	27	Avg.
O_2 % By Volume	1.0	.9	1.0	1.0
CO PPM	2000+	2000+	1900	
NO_x PPM	220	215	220	
SO_2 PPM	2422	2358	2354	
SO_3 PPM	18.5	19.1	17.4	
CO - PPM Adj. To 3% O_2	2000+	2000+	1710	2000+
NO_x - PPM Adj. To 3% O_2	198	193	198	196
SO_2 - PPM Adj. To 3% O_2	2180	2112	2119	2137
SO_3 - PPM Adj. To 3% O_2	16.6	17.1	15.7	16.5
% Conversion of SO_2 to SO_3	.76	.80	.74	.77

16. Shoreside Boiler Fuel-Water Emulsions Study
Neat Oil (0% Water) Emission Data

Reference 24

Fuel Oil #6 Used During Testing

TABLE II-1

SUMMARY OF PARTICULATE EMISSIONS DURING PRE LONG TERM NEAT OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	ISOKINETIC %	SAMPLE VOLUME DSCF	STACK GAS FLOW RATE ACFM	STACK GAS FLOW RATE DSCFM	FLUE GAS % MOISTURE	FLUE GAS TEMP. ^{o}F	AVERAGE ORSAT % O_2 (DRY)	Fd $\frac{DSCF}{10^6 BTU}$	lb/DSCF	lb/10^6 BTU
2	9/10/80	1030-1330	35.4	108	27.6	4420	2500	11.99	366	4.5	9406.9	7.01×10^{-6}	0.0840
3a	9/10/80	1430-1730	31.4	102	43.4	7260	4220	12.15	341	5.3		3.97×10^{-6}	0.0500
3b	9/10/80	1535-1835	31.4	108	43.1	6750	3920	12.52	339	4.7		4.23×10^{-6}	0.0513
4a	9/11/80	1336-1700	32.8	113	69.9	10400	6130	10.43	345	5.1		5.39×10^{-6}	0.0671
4b	9/11/80	1415-1715	32.8	106	46.2	7530	4260	14.39	344	5.1		6.4×10^{-6}	0.0779
5a	9/12/80	0900-1150	95.6	108	91.5	18000	8370	12.50	545	4.3		11.5×10^{-6}	0.136
5b	9/12/80	0930-1216	95.6	105	88.8	17800	8270	12.53	542	4.3		10.1×10^{-6}	0.120
6a	9/12/80	1340-1640	97.8	105	91.7	18500	8630	11.82	545	3.6		9.64×10^{-6}	0.110
6b	9/12/80	1400-1700	97.8	106	85.2	16900	7900	12.11	544	3.6		8.87×10^{-6}	0.101
7	9/15/80	0925-1300	94.8	108	70.3	14000	6450	11.76	549	3.4		12.4×10^{-6}	0.139

TABLE H-2

SUMMARY OF NITROGEN OXIDE EMISSIONS FOR BOILER NO. 3 DURING PRE LONG TERM NEAT OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	AVG. NO_x AS NO (ppm)	AVG. NO_x AS NO (lb/DSCF)	AVG. NO_x AS NO_2 (lb/DSCF)	AVERAGE ORSAT % O_2 (DRY)	Fd DSCF/10^6 BTU	NO_x AS NO_2 lb/10^6 BTU
1a	9/9/80	1255-1355	36.8	136	1.06×10^{-5}	1.62×10^{-5}	5.1	9406.9	0.201
1b	9/9/80	1355-1635	36.8	124	9.62×10^{-6}	1.47×10^{-5}	5.8		0.192
2a	9/10/80	0930-1130	35.4	106	8.22×10^{-6}	1.26×10^{-5}	4.1		0.148
2b	9/10/80	1130-1330	35.4	128	9.93×10^{-6}	1.52×10^{-5}	4.7		0.185
3a	9/10/80	1430-1600	31.4	120	9.31×10^{-6}	1.43×10^{-5}	5.4		0.181
3b	9/10/80	1600-1830	31.4	120	9.31×10^{-6}	1.43×10^{-5}	4.8		0.174
4a	9/11/80	1330-1430	32.8	91	7.06×10^{-6}	1.08×10^{-5}	5.4		0.137
4b	9/11/80	1430-1530	32.8	97	7.52×10^{-6}	1.15×10^{-5}	6.2		0.154
5a	9/12/80	0830-1100	95.6	171	1.33×10^{-5}	2.03×10^{-5}	4.4		0.242
5b	9/12/80	1100-1330	95.6	165	1.28×10^{-5}	1.96×10^{-5}	4.3		0.232
6a	9/12/80	1330-1530	97.8	154	1.19×10^{-5}	1.83×10^{-5}	3.6		0.208
6b	9/12/80	1530-1720	97.8	135	1.05×10^{-5}	1.61×10^{-5}	3.6		0.183
7a	9/15/80	0830-1000	94.8	178	1.38×10^{-5}	2.12×10^{-5}	3.4		0.238
7b	9/15/80	1000-1200	94.8	142	1.10×10^{-5}	1.69×10^{-5}	3.4		0.190

TABLE H-3

SUMMARY OF PARTICULATE EMISSIONS DURING POST LONG TERM NEAT OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	ISOKINETIC %	SAMPLE VOLUME DSCF	STACK GAS FLOW RATE ACFM	STACK GAS FLOW RATE DSCFM	FLUE GAS % MOISTURE	FLUE GAS TEMP. °F	AVERAGE ORSAT % O_2 (DRY)	Fd $\frac{DSCF}{10^6 BTU}$	lb/DSCF	lb/10^6 BTU
2a	5/5/81	0900-1200	39.8	98.1	57.1	11053	5906	11.86	410	6.2	9272	2.07×10^{-6}	0.0273
2b	5/5/81	1035-1330	39.8	104.1	48.6	10350	5553	11.35	412	6.2		3.63×10^{-6}	0.0479
3a	5/5/81	1435-1730	40.4	106.5	51.8	9212	4939	11.37	411	6.1		9.99×10^{-6}	0.131*
3b	5/5/81	1525-1800	40.4	106.0	46.7	10250	5508	11.19	411	6.1		2.53×10^{-6}	0.0332
4a	5/6/81	0821-1116	110.9	102.0	91.8	22600	9140	11.60	679	5.1		5.11×10^{-6}	0.0626
4b	5/6/81	0920-1210	110.9	93.1	84.3	20000	9190	12.20	680	5.1		5.66×10^{-6}	0.0694
5a	5/6/81	1330-1630	99.4	101.4	75.3	18000	7540	14.70	606	3.3		4.30×10^{-6}	0.0474
5b	5/6/81	1430-1715	99.4	103.3	77.8	17800	7640	12.0	606	3.3		4.32×10^{-6}	0.0476
6a	5/7/81	0900-1145	108.1	102.3	100.7	23100	9990	10.70	642	4.1		3.73×10^{-6}	0.0430
6b	5/7/81	0950-1250	108.1	105.6	92.7	20700	8910	11.20	640	4.1		4.24×10^{-6}	0.0489

* Test 3a particulate data not believable based on disagreement with results of four (4) other tests run at essentially the same load. Questionable results believed to be due to pick-up of particulate from duct floor during test. Results not used in data analysis.

TABLE H-4

SUMMARY OF NITROGEN OXIDE EMISSIONS DURING POST LONG TERM NEAT OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	AVG. NO_x AS NO (ppm)	AVG. NO_x AS NO (lb/DSCF)	AVG. NO_x AS NO_2 (lb/DSCF)	AVERAGE ORSAT % O_2 (DRY)	Fd DSCF/10^6 BTU	NO_x AS NO_2 lb/10^6 BTU
1	5/4/81	1500-1530	39.1	93	7.24×10^{-6}	11.1×10^{-6}	7.1	9272	0.156
2a	5/5/81	0900-1115	39.8	99	7.71×10^{-6}	11.8×10^{-6}	6.2		0.155
2b	5/5/81	1115-1330	39.8	96	7.47×10^{-6}	11.4×10^{-6}	6.2		0.150
3a	5/5/81	1435-1545	40.4	95	7.40×10^{-6}	11.3×10^{-6}	6.1		0.148
3b	5/5/81	1545-1800	40.4	100	7.78×10^{-6}	11.9×10^{-6}	6.1		0.156
4a	5/6/81	0821-1030	110.9	160	12.4×10^{-6}	19.0×10^{-6}	5.1		0.233
4b	5/6/81	1030-1210	110.9	160	12.4×10^{-6}	19.0×10^{-6}	5.1		0.233
5a	5/6/81	1330-1500	99.4	145	11.3×10^{-6}	17.3×10^{-6}	3.3		0.190
5b	5/6/81	1500-1715	99.4	150	11.7×10^{-6}	17.9×10^{-6}	3.3		0.197
6a	5/7/81	0900-1110	108.1	148	11.5×10^{-6}	17.6×10^{-6}	4.1		0.203
6b	5/7/81	1110-1250	108.1	150	11.7×10^{-6}	17.9×10^{-6}	4.1		0.206

TABLE H-5

SUMMARY OF PARTICULATE EMISSIONS DURING PRE LONG TERM EMULSIFIED OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	ISOKINETIC %	SAMPLE VOLUME DSCF	STACK GAS FLOW RATE ACFM	STACK GAS FLOW RATE DSCFM	FLUE GAS % MOISTURE	FLUE GAS TEMP. ^{o}F	AVERAGE ORSAT % O_2 (DRY)	Fd $\frac{DSCF}{10^6 BTU}$	lb/DSCF	lb/10^6 BTU
2	6/22/81	1329-1558	41.4	104	45.2	7880	4310	12.1	377	4.4	9369	2.24×10^{-6}	0.0266
3a	6/23/81	0752-1055	40.5	105	52.2	9080	4970	12.1	381	5.2		16.1×10^{-6}	0.201*
3b	6/23/81	0850-1150	40.5	105	39.8	6920	3840	11.1	382	5.2		2.28×10^{-6}	0.0285
4a	6/23/81	1256-1549	40.3	105	47.8	8270	4570	12.1	377	5.0		2.16×10^{-6}	0.0232
4b	6/23/81	1353-1700	40.3	105	44.1	7750	4300	11.7	378	5.0		1.88×10^{-6}	0.0266
5a	6/24/81	0810-1059	103.8	100	92.4	20200	9220	11.2	574	4.5		2.49×10^{-6}	0.0297
5b	6/24/81	0905-1154	103.8	101	90.1	20000	9090	11.0	581	4.7		2.47×10^{-6}	0.0299
6a	6/24/81	1333-1610	96.6	102	81.9	16600	7990	11.8	540	4.1		2.64×10^{-6}	0.0316
6b	6/24/81	1431-1705	96.6	104	76.2	16100	7460	12.1	545	4.0		2.56×10^{-6}	0.0297
7a	6/25/81	0813-1048	96.8	103	82.4	17600	7990	12.8	554	4.1		2.36×10^{-6}	0.0275

* Test 3a particulate data not believable based on disagreement with results of four (4) other tests run at essentially the same load. Questionable results believed to be due to pick-up of particulate from duct floor during test. Results not used in statistical analysis.

TABLE H-6

SUMMARY OF NITROGEN OXIDE EMISSIONS DURING PRE LONG TERM EMULSIFIED OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	AVG. NO_x AS NO (ppm)	AVG. NO_x AS NO (lb/DSCF)	AVG. NO_x AS NO_2 (lb/DSCF)	AVERAGE ORSAT % O_2 (DRY)	Fd DSCF/10^6 BTU	NO_x AS NO_2 lb/10^6 BTU
2a	6/22/81	1330-1430	41.4	82	6.4×10^{-6}	9.7×10^{-6}	4.5	9369	0.116
2b	6/22/81	1430-1600	41.4	80	6.2×10^{-6}	9.5×10^{-6}	4.3		0.119
3a	6/23/81	0752-1055	40.5	79	6.1×10^{-6}	9.4×10^{-6}	5.2		0.117
3b	6/23/81	1050-1150	40.5	80	6.2×10^{-6}	9.5×10^{-6}	5.2		0.119
4a	6/23/81	1256-1549	40.3	91	7.1×10^{-6}	10.8×10^{-6}	5.0		0.133
4b	6/23/81	1353-1700	40.3	93	7.2×10^{-6}	11.1×10^{-6}	5.0		0.137
5a	6/24/81	0810-1059	103.8	135	10.5×10^{-6}	16.1×10^{-6}	4.5		0.192
5b	6/24/81	0905-1154	103.8	135	10.5×10^{-6}	16.1×10^{-6}	4.7		0.195
6a	6/24/81	1333-1610	96.6	130	10.1×10^{-6}	15.5×10^{-6}	4.1		0.181
6b	6/24/81	1431-1705	96.6	130	10.1×10^{-6}	15.5×10^{-6}	4.0		0.180
7a	6/25/81	0810-0940	96.8	125	9.7×10^{-6}	14.9×10^{-6}	4.1		0.140
7b	6/25/81	0940-1100	96.8	127	9.8×10^{-6}	15.1×10^{-6}	4.1		0.176

TABLE H-7

SUMMARY OF PARTICULATE EMISSIONS DURING POST LONG TERM EMULSIFIED OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	ISOKINETIC %	SAMPLE VOLUME DSCF	STACK GAS FLOW RATE ACFM	STACK GAS FLOW RATE DSCFM	FLUE GAS % MOISTURE	FLUE GAS TEMP. ^{o}F	AVERAGE ORSAT % O_2 (DRY)	Fd $\frac{DSCF}{10^6 BTU}$	lb/DSCF	lb/10^6 BTU
1	3/22/82	1355-1600	102.4	104	38.7	21800	9723	10.8	589	3.9	9205	6.61×10^{-6}	0.0748
2a	3/23/82	0815-1025	99.9	107	37.1	20004	9113	10.3	583	4.2		30.9×10^{-6}	0.356*
2b	3/23/82	0905-1045	99.9	108	36.0	19445	8723	11.0	591	4.2		5.09×10^{-6}	0.0586
3a	3/23/82	1245-1450	96.7	105	35.9	19771	9044	12.4	556	2.8		5.75×10^{-6}	0.0610
3b	3/23/82	1330-1535	96.7	107	34.3	18316	8342	12.5	557	2.8		6.69×10^{-6}	0.0710
4a	3/24/82	0730-1040	34.7	105	53.5	5378	3137	12.6	339	4.5		4.57×10^{-6}	0.0536
4b	3/24/82	0900-1125	34.7	103	60.0	5794	3367	12.6	342	4.5		4.80×10^{-6}	0.0564
5a	3/24/82	1325-1530	34.1	103	33.2	5241	3055	12.0	345	4.5		3.56×10^{-6}	0.0420
5b	3/24/82	1400-1605	34.1	102	43.3	6249	3658	12.0	342	4.5		3.95×10^{-6}	0.0463
6	3/25/82	0720-0900	34.6	104	37.1	5662	3290	12.2	343	4.6		4.95×10^{-6}	0.0584

* Test 2a particulate data not believable based on disagreement with results of four (4) other tests run at essentially the same load. Questionable results believed to be due to pick-up of particulate from duct floor during test. Results not used in statistical analysis.

TABLE H-8

SUMMARY OF NITROGEN OXIDE EMISSIONS DURING POST LONG TERM EMULSIFIED OIL TESTS

TEST NO.	DATE	TIME	% STEAM LOAD	AVG. NO_x AS NO (ppm)	AVG. NO_x AS NO (lb/DSCF)	AVG. NO_x AS NO_2 (lb/DSCF)	AVERAGE ORSAT % O_2 (DRY)	Fd DSCF/10^6 BTU	NO_x AS NO_2 lb/10^6 BTU
1a	3/22/82	1315-1515	102.4	112	8.72×10^{-6}	1.34×10^{-5}	3.9	9205	0.152
1b	3/22/82	1515-1715	102.4	129	10.02×10^{-6}	1.54×10^{-5}	3.9	↓	0.174
2a	3/23/82	0715-0915	99.9	132	10.28×10^{-6}	1.58×10^{-5}	4.2		0.182
2b	3/23/82	0915-1115	99.9	135	10.47×10^{-6}	1.61×10^{-5}	4.2		0.185
3a	3/23/82	1200-1400	96.7	138	10.67×10^{-6}	1.64×10^{-5}	2.8		0.174
3b	3/23/82	1400-1600	96.7	170	13.19×10^{-6}	2.02×10^{-5}	2.8		0.215
4a	3/24/82	0755-0955	34.7	70	5.41×10^{-6}	8.30×10^{-6}	4.5		0.097
4b	3/24/82	0955-1100	34.7	75	5.80×10^{-6}	8.89×10^{-6}	4.5		0.104
5a	3/24/82	1315-1515	34.1	77	5.99×10^{-6}	9.18×10^{-6}	4.5		0.108
5b	3/24/82	1515-1715	34.1	80	6.18×10^{-6}	9.48×10^{-6}	4.5		0.111
6a	3/25/82	0700-0900	34.6	73	5.69×10^{-6}	8.72×10^{-6}	4.3		0.101
6b	3/25/82	0900-1100	34.6	80	6.24×10^{-6}	9.56×10^{-6}	4.3		0.111

DATA SUMMARY ON NEAT OIL FUEL #6
FUEL CONSUMPTION[a]

Test Performed	Test Date	Heat Input (10^6 Btu/hr)	Percent of Load	Fuel Characteristics	
				sp. gr.	lb/hr
Pre-Long Term Tests					
1a	9/9/80	13.15	36.8	0.9567	711.4
1b	9/9/80	13.15	36.8	0.9567	711.4
2a	9/10/80	12.80	35.4	0.9567	692.8
2b	9/10/80	12.80	35.4	0.9567	692.8
3a	9/10/80	11.09	31.4	0.9567	599.8
3b	9/10/80	11.09	31.4	0.9567	599.8
4a	9/11/80	11.61	32.8	0.9567	628.1
4b	9/11/80	11.61	32.8	0.9567	628.1
5a	9/12/80	35.40	95.6	0.9567	1915.6
5b	9/12/80	35.40	95.6	0.9567	1915.6
6a	9/12/80	35.53	97.8	0.9567	1922.4
6b	9/12/80	35.53	97.8	0.9567	1922.4
7a	9/15/80	35.14	94.8	0.9567	1901.4
7b	9/15/80	35.14	94.8	0.9567	1901.4
Post-Long Term Tests					
1	5/4/81	14.09	39.1	0.9194	733.0
2a	5/5/81	14.32	39.8	0.9194	744.8
2b	5/5/81	14.32	39.8	0.9194	744.8
3a	5/5/81	14.47	40.4	0.9194	752.7
3b	5/5/81	14.47	40.4	0.9194	752.7
4a	5/6/81	42.97	110.9	0.9194	2235.1
4b	5/6/81	42.97	110.9	0.9194	2235.1
5a	5/6/81	37.47	99.4	0.9194	1949.0
5b	5/6/81	37.47	99.4	0.9194	1949.0
6a	5/7/81	41.32	108.1	0.9194	2149.3
6b	5/7/81	41.32	108.1	0.9194	2149.3

17. Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Outboard Motors
(For Pleasure Craft Data Base)

Reference 25

Note: It is assumed that inboard engine emissions are comparable to outboard engine emission factors and are treated as such for data base input.

TABLE 2. AVERAGE POWER OUTPUT OBSERVED DURING OUTBOARD TESTS

	Average Observed Propshaft Horsepower/Rpm in Modes by Engine				
	OMC 4 hp	OMC 9.5 hp	Chrysler 35 hp		Mercury 65 hp
Mode	x = 3	x = 2.5	x = 2.5	x = 3	x = 2.5
1	2.73/4500	7.29/4500	28.4/5000	28.4/5000	53.4/5200
2	1.74/4000	5.34/4000	16.1/4000	14.3/4000	45.6/4800
3	0.75/3000	2.59/3000	7.9/3000	6.1/3000	29.2/4000
4	0.23/2000	0.95/2000	2.9/2000	1.8/2000	13.0/2890
5	0.05/1250	0.17/1000	0.5/1000	0.2/1000	5.2/2000
6	Idle/(1050)	Idle/(700)	Idle/(1000)	Idle/(1100)	0.9/1000
7	--	--	--	--	Idle/(800)

Reference

TABLE 3. TOTAL MASS EMISSIONS AND MASS EMISSIONS RETAINED IN WATER PHASE (EXPERIMENTALLY) FOR FOUR OUTBOARD MOTORS

		Raw Mass Emission Rate, g/hr				Loss in Water (Experimental), g/hr			
		Johns.	Johns.	Chrys.	Merc.	Johns.	Johns.	Chrys.	Merc.
Mode	Gas	4	9.5	35	65	4	9.5	35	65
1	HC	577	792	2880	6340	148	294	1460	2220
	CO	699	2140	9310	8910	64.0	79.9	384	260
	CO_2	2660	5830	13500	32800	857	2330	5300	14300
	NO_x	5.5	6.3	9.7	81.5	1.4	0.5	2.5	14.4
	O_2	1560	1970	5230	17700	-86.9	-71.8	-301	215
	H_2O	1480	4020	12300	19900	1210	3190	9800	16500
2	HC	324	813	1850	4660	97.8	351	686	1350
	CO	587	1690	5760	6170	104	83.2	319	270
	CO_2	1980	5350	9803	29200	723	2240	3910	13300
	NO_x	1.3	3.8	6.9	83.4	0.1	0.4	1.9	16.1
	O_2	1010	2040	3350	12500	60.4	-106	-152	-428
	H_2O	1110	3560	8300	16900	931	2800	6600	14300
3	HC	212	827	1550	2730	63.4	365	572	977
	CO	474	1520	4020	5030	51.7	71.5	115	177
	CO_2	1350	3790	6540	19000	426	1520	2730	7570
	NO_x	0.6	1.9	3.5	19.2	0.0	0.4	1.6	1.5
	O_2	565	2020	2830	6750	-36.1	28.9	-177	-299
	H_2O	806	2720	5650	11660	671	2120	4440	9920
4	HC	168	638	1040	2120	61.5	310	390	743
	CO	303	951	2310	4850	25.2	68.0	138	193
	CO_2	748	2180	4130	10300	294	867	998	3830
	NO_x	0.2	0.7	1.7	3.2	0.0	0.2	0.7	0.9
	O_2	378	1340	1880	5670	-22.4	43.2	-45.6	-89.5
	H_2O	507	1650	3440	7760	427	1280	2700	6590
5	HC	176	413	746	1980	54.0	200	286	552
	CO	275	472	1080	2890	24.2	45.1	80.5	6.3
	CO_2	464	885	1850	6480	124	342	772	2450
	NO_x	0.1	0.1	0.6	0.8	0.0	0.0	0.4	0.3
	O_2	343	769	1170	5000	-17.6	33.3	63.1	34.6
	H_2O	369	730	1600	4840	306	558	1230	4030
6	HC	198	402	1030	2170	64.0	190	378	537
	CO	242	365	1010	2590	22.0	31.0	73.6	116
	CO_2	373	662	1630	4300	100	261	666	1550
	NO_x	0.0	0.1	0.6	0.8	0.0	0.0	0.4	0.4
	O_2	358	729	1410	5750	-1.6	32.5	48.6	67.8
	H_2O	315	564	1480	3780	258	422	1100	3030
7	HC	--	--	--	1870	--	--	--	389
	CO	--	--	--	1610	--	--	--	70.4
	CO_2	--	--	--	2440	--	--	--	799
	NO_x	--	--	--	0.5	--	--	--	0.2
	O_2	--	--	--	5610	--	--	--	138
	H_2O	--	--	--	2350	--	--	--	1760

TEST DATA ON JOHNSON 9.5 hp OUTBOARD MOTOR

	FUEL CONSUMPTION, lb-/hr								
	RUN NUMBER								AVERAGE OR TYPICAL VALUE
MODE	1	2	3	4	5	6	7	8	
1	8.17	8.11	8.34	8.09	7.81	8.08	7.95	8.37	8.11
1A	8.05	8.19	8.37	8.14	7.86	8.17	8.00	8.37	8.14
2	7.43	7.46	7.52	7.09	7.22	7.35	7.36	7.31	7.35
2A	7.43	7.57	7.54	7.05	7.22	7.20	7.38	7.38	7.35
3	6.17	6.06	6.33	5.91	5.88	6.18	6.27	5.96	6.09
3A	6.19	6.19	6.37	6.90	5.86	6.19	6.30	5.97	6.12
4	4.08	4.11	3.94	3.80	3.74	4.09	4.18	3.74	3.96
4A	4.09	4.11	4.07	3.73	3.64	4.07	4.13	3.73	3.95
5	2.18	1.95	1.99	1.60	2.21	2.25	2.00	2.11	2.03
5A	2.18	1.98	1.93	1.55	2.32	2.20	2.01	2.10	2.03
6	1.68	1.85	1.59	1.56	1.76	1.75	1.85	1.88	1.74
6A	1.83	1.80	1.63	1.52	1.71	1.77	1.84	1.86	1.75

	FUEL CONSUMPTION, g/hr								
	RUN NUMBER								AVERAGE OR TYPICAL VALUE
MODE	1	2	3	4	5	6	7	8	
1	3710	3680	3780	3670	3540	3670	3600	3800	3680
1A	3660	3720	3800	3690	3570	3710	3630	3800	3700
2	3370	3290	3420	3220	3280	3340	3340	3320	3330
2A	3370	3430	3420	3200	3280	3260	3350	3350	3330
3	2800	2750	2870	2680	2670	2800	2850	2700	2770
3A	2810	2810	2890	2680	2660	2810	2860	2710	2780
4	1850	1870	1790	1730	1700	1860	1900	1700	1800
4A	1860	1870	1850	1690	1650	1850	1870	1690	1790
5	990	886	904	724	1000	1020	910	960	925
5A	990	901	875	705	1050	1000	914	955	924
6	764	840	723	706	797	791	839	855	790
6A	839	818	740	691	777	803	834	845	793

TEST DATA ON JOHNSON 4R71 OUTBOARD MOTOR
1/4/72 – 1/27/72 11-2869-01

	FUEL CONSUMPTION, lb-/hr (NORMAL AND "A" MODES)							
	RUN NUMBER							AVERAGE OR TYPICAL VALUE
MODE	5	6	7	8	9	* 10	* 11	
1				4.11	4.04	3.34	3.42	4.08/*3.38
1A								
2				2.76	2.80	2.61	2.58	2.78/*2.60
2A								
3				1.94	1.87	1.82	2.04	1.92
3A								
4				1.25	1.19	1.16	1.29	1.22
4A								
5				1.00	1.07	0.93	1.05	1.01
5A								
6				0.90	0.97	0.98	0.98	0.96
6A								

* NEW FUEL PUMP INSTALLED PRIOR TO RUN 10

	FUEL CONSUMPTION, g/hr (NORMAL AND "A" MODES)							
	RUN NUMBER							AVERAGE OR TYPICAL VALUE
MODE	5	6	7	8	9	* 10	* 11	
1				1870	1830	1520	1550	1850/*1530
1A								
2				1250	1270	1180	1170	1260/*1180
2A								
3				880	848	825	925	870
3A								
4				567	539	526	585	553
4A								
5				454	485	422	476	458
5A								
6				408	440	445	445	435
6A								

TEST DATA ON MERCURY 650 OUTBOARD MOTOR

2/21/72 - 2/28/72 11-2869-01

	FUEL CONSUMPTION, lb-/hr					
	RUN NUMBER					AVERAGE OR TYPICAL VALUE
MODE	2	3	4	5	6	
1	46.9	46.9	45.7	46.4	44.8	46.1
1 A	47.4	47.1	46.1	46.5	46.7	46.8
2	36.9	37.5	37.7	37.0	37.3	37.3
2 A	36.5	37.2	38.2	37.2	37.0	37.2
3	24.7	24.4	24.4	25.0	24.9	24.7
3 A	24.9	24.4	24.4	24.9	24.9	24.7
4	16.4	17.3	16.8	17.8	16.9	17.0
4 A	16.4	17.5	16.8	17.9	17.3	17.2
5	12.0	12.2	11.8	12.1	11.8	12.0
5 A	12.0	12.5	12.1	11.8	11.7	12.0
6	10.4	10.3	10.4	10.7	11.0	10.6
6 A	10.6	10.4	10.4	10.7	11.1	10.6
7	7.14	6.89	7.03	8.89	8.08	7.61
7 A	7.09	7.06	6.81	8.56	8.02	7.51

	FUEL CONSUMPTION, #/hr					
	RUN NUMBER					AVERAGE OR TYPICAL VALUE
MODE	2	3	4	5	6	
1	21,300	21,300	20,700	21,000	20,300	20,900
1 A	21,500	21,400	20,900	21,100	21,200	21,200
2	16,700	17,000	17,100	16,800	16,900	16,900
2 A	16,600	16,900	17,300	16,900	16,800	16,900
3	11,200	11,100	11,100	11,300	11,300	11,200
3 A	11,300	11,100	11,100	11,300	11,300	11,200
4	7440	7850	7620	8070	7670	7710
4 A	7440	7940	7620	8120	7850	7800
5	5440	5540	5350	5490	5350	5440
5 A	5440	5670	5490	5350	5310	5440
6	4720	4670	4720	4850	4990	4810
6 A	4810	4720	4720	4850	5030	4810
7	3240	3130	3190	4030	3670	3450
7 A	3220	3200	3090	3880	3640	3410

TEST DATA ON CHRYSLER 35 hp OUTBOARD MOTOR

	FUEL CONSUMPTION, lb-/hr							AVERAGE OR TYPICAL VALUE	
	RUN NUMBER								
MODE	1	2	3	4	5	6	7	1-5	6&7
1	26.0	27.0	25.6	25.8	25.0	——	——	25.9	——
1A	25.8	26.8	25.3	25.8	26.0	——	——	25.7	——
2	16.9	16.8	16.8	18.0	17.2	17.2	17.2	17.1	17.2
2A	17.0	17.0	17.0	17.9	17.5	17.4	17.3	17.2	17.4
3	12.4	12.3	11.8	12.7	12.5	12.2	12.4	12.3	12.3
3A	12.3	12.2	12.1	12.6	12.5	12.1	12.5	12.3	12.3
4	7.26	7.28	7.88	7.95	7.94	7.88	7.85	7.66	7.86
4A	7.44	7.32	7.92	7.85	7.92	7.92	7.85	7.69	7.88
5	3.79	3.71	4.33	4.48	4.25	4.55	4.49	4.11	4.44
5A	3.89	3.61	4.33	4.41	4.17	4.52	4.34	4.08	4.51
6	4.17	3.93	4.94	4.90	4.58	——	——	4.51	——
6A	4.24	4.00	4.92	4.86	4.58	——	——	4.52	——

	FUEL CONSUMPTION, #/hr							AVERAGE OR TYPICAL VALUE	
	RUN NUMBER								
MODE	1	2	3	4	5	6	7	1-5	6&7
1	11,800	12,200	11,600	11,700	11,400	——	——	11,750	——
1A	11,700	12,200	11,500	11,700	11,300	——	——	11,670	——
2	7660	7620	7590	8170	7810	7820	7800	7770	7810
2A	7700	7700	7640	8120	7930	7900	7850	7820	7870
3	5640	5570	5360	5750	5680	5520	5610	5600	5560
3A	5580	5510	5470	5790	5660	5480	5660	5580	5570
4	3290	3300	3570	3610	3600	3570	3590	3480	3570
4A	3380	3320	3590	3560	3590	3590	3560	3490	3580
5	1720	1680	1960	2030	1930	2060	1970	1860	2020
5A	1770	1640	1970	2000	1890	2050	2040	1850	2040
6	1890	1780	2240	2220	2080	——	——	2040	——
6A	1920	1820	2230	2210	2080	——	——	2050	——

18. U. S. Coast Guard Pollution Abatement Program Two Stroke Cycle Outboard Gasoline Engine Emissions (for Pleasure Craft Data Base)

Reference 26

NOTE: It is assumed that inboard engine emission factors are comparable to outboard engine emissions factors and are treated as such for data base input.

TABLE 2. APPLIED HP FOR TEST ENGINES

Speed (RPM)	1959 Johnson	1965 Mercury	1962 Mercury	1974 Evinrude	1972 Mercury
700-800	-	-	-	-	-
1000	1.16	1.05	0.937	0.93	0.715
2000	6.58	5.96	5.58	5.27	4.05
3000	18.14	16.43	15.30	14.51	11.15
4000	37.25	33.75	31.57	29.80	22.89
4500	50.00	-	-	40.00	-
5000	-	58.93	55.16	-	40.00
5200	-	65.00	-	-	-
5500	-	-	70.00	-	-

TWO STROKE OUTBOARD ENGINE EMISSION DATA[a,b]

Engine	HP	Load %	Fuel Cons. gal/hr	Total Emissions (g/hr)		
				CO	NO_x	THC
Johnson 1959	Idle	-	-	2,850	2.6	3,050
50 hp rated	1.16	2.3	-	4,500	3.0	3,200
	6.58	13.2	-	7,000	4.5	7,050
	18.14	36.3	-	10,000	8.6	6,150
	37.25	74.5	-	7,600	18.5	5,800
	50.00	100.0	-	7,650	-	4,650
Mercury 1964	1.05	1.6	-	700	1.0	1,550
65 hp rated	5.96	9.2	-	750	1.2	1,780
	16.43	25.3	-	1,350	2.5	2,250
	33.73	51.9	-	4,950	4.5	2,700
	58.93	90.7	-	6,650	12.0	3,250
	65.00	100.0	-	9,300	27.0	4,500
Mercury 1962	0.937	1.3	1.35	1,200	0.7	1,700
70 hp rated	5.57	8.0	2.45	2,000	1.1	2,300
	15.38	22.0	3.29	4,400	2.5	3,750
	31.57	45.1	3.92	7,500	4.5	3,800
	55.16	78.8	5.32	9,500	10.8	3,050
	70.00	100.0	6.47	12,600	21.0	3,700
Evinrude 1974	Idle	2.3	-	900	0.4	900
40 hp rated	0.93	2.3	-	950	0.6	760
	5.27	13.2	-	700	1.7	950
	14.51	36.3	-	1,750	6.2	1,075
	29.80	74.5	-	5,750	11.1	1,950
	40.00	100.0	-	6,250	19.3	2,500
Mercury 1972	Idle	-	-	500	0.2	450
40 hp rated	0.715	1.8	-	550	0.2	300
	4.05	10.1	-	1,450	0.85	750
	11.15	27.9	-	1,250	3.8	750
	22.89	57.2	-	4,600	5.55	1,450
	40.00	100.0	-	4,200	20.8	2,050

[a]Reference 26.
[b]Gasoline density = 6.17 lb/gal.

TWO STROKE OUTBOARD ENGINE EMISSIONS DATA [a,b]

Engine	HP	Load %	Fuel Cons. gal/hr	Total Emissions (g/hr) HC	CO	NO_x
Johnson	2.73	68.3	-	577	699	5.5
4 hp	1.74	43.5	-	324	587	1.3
	0.75	18.8	-	212	474	0.6
	0.23	5.8	-	168	303	0.2
	0.05	1.3	-	176	275	0.1
	Idle	-	-	198	242	0
Johnson	7.29	83.2	-	792	2,140	6.3
9.5 hp	5.34	56.2	-	813	1,690	3.8
	2.59	27.3	-	827	1,520	1.9
	0.95	10.0	-	638	951	0.7
	0.17	1.8	-	413	472	0.1
	Idle	-	-	402	365	0.1
Chrysler	28.4	81.1	-	2,880	9,310	9.7
35 hp	16.1	46.0	-	1,850	5,760	6.9
	7.9	22.6	-	1,550	4,020	3.5
	2.9	8.3	-	1,040	2,310	1.7
	0.5	1.4	-	746	1,080	0.6
	Idle	-	-	1,030	1,010	0.6
Mercury	53.4	82.2	-	6,340	8,910	81.5
65 hp	45.6	70.2	-	4,660	6,170	83.4
	29.2	44.9	-	2,730	5,030	19.2
	13.0	20.0	-	2,120	4,850	3.2
	5.2	8.0	-	1,980	2,890	0.8
	0.9	1.4	-	2,170	2,590	0.8
	Idle		-	1,870	1,610	0.5

[a]Reference 26.
[b]Gasoline density = 6.17 lbs/gal.

TABLE 7. WATER/EXHAUST MIXING RESULTS

MODE	GAS	MASS EMISSIONS (g/hr)					EMISSIONS RETAINED IN WATER (g/hr)					EMISSIONS VENTED TO AIR (g/hr)				
		JOHNSON 1959, 50 HP	MERCURY 1964, 65 HP	MERCURY 1962, 70 HP	EVINRUDE 1974, 40 HP	MERCURY 1972, 40 HP	JOHNSON 1959, 50 HP	MERCURY 1964, 65 HP	MERCURY 1962, 70 HP	EVINRUDE 1974, 40 HP	MERCURY 1972, 40 HP	JOHNSON 1959, 50 HP	MERCURY 1964, 65 HP	MERCURY 1962, 70 HP	EVINRUDE 1974, 40 HP	MERCURY 1972, 40 HP
1	CO	2850	700	1200	900	500	201	386	366	246	112	2649	314	834	654	388
	CO_2	7000	3125	2000	1200	1250	5230	2744	1483	1005	1062	1770	381	517	195	188
	NO_x	2.6	1.0	.75	0.4	0.2	1.2	0.6	0.4	0.23	0.12	1.4	0.4	0.35	0.17	0.08
	THC	3050	1550	1700	900	450	597	934	910	474	235	2453	616	790	426	215
2	CO	4500	750	2000	950	550	344	427	510	245	160	4156	323	1490	705	390
	CO_2	9125	3625	2900	2100	1400	6998	3093	2076	1715	1221	2127	532	824	385	179
	NO_x	3.0	1.2	1.1	0.6	0.2	1.35	0.77	0.55	0.24	0.12	1.65	0.43	0.55	0.36	0.08
	THC	3200	1780	2300	760	300	643	1033	1411	352	160	2557	747	889	408	140
3	CO	7000	1350	4400	700	1450	1123	624	846	142	502	5877	726	3554	558	948
	CO_2	9250	6750	4850	5750	3300	7145	5759	3507	4769	2933	2105	991	1343	981	367
	NO_x	4.5	2.5	2.5	1.7	0.85	1.96	1.36	1.05	0.24	0.36	2.54	1.14	1.45	1.46	0.49
	THC	7050	2250	3750	950	750	2641	1274	2135	452	426	4409	976	1615	498	324
4	CO	10000	4950	7500	1750	1250	1773	2221	1209	554	414	8227	2729	6291	1196	836
	CO_2	12500	10625	8400	9500	6000	9825	9132	5829	7928	5493	2675	1493	2571	1572	507
	NO_x	8.6	4.5	4.5	6.2	3.8	0.65	1.96	1.22	1.74	1.75	7.95	2.54	3.28	4.46	2.05
	THC	6150	2700	3800	1075	750	1825	1631	2116	483	441	4325	1069	1684	592	309
5	CO	7600	6650	9500	5750	4600	1747	8367	925	1662	1664	5853	2783	8575	4088	2936
	CO_2	20000	18000	13500	12200	7600	16052	15809	10292	10009	6816	3948	2191	3208	2191	784
	NO_x	18.5	12.0	10.8	11.1	5.55	.98	5.62	2.05	3.76	2.60	17.52	6.38	8.75	7.34	2.95
	THC	5800	3250	3050	1950	1450	1412	1508	1419	996	855	4388	1742	1631	954	595
6	CO	7650	9300	12600	6250	4200	-	5873	474	1837	1191	-	3427	12126	4413	3009
	CO_2	-	-	20200	17400	13800	-	-	14815	14706	11752	-	-	5385	2694	2048
	NO_x	-	27.0	21.0	19.3	20.8	-	13.8	5.39	6.82	10.1	-	13.2	15.61	12.48	10.7
	THC	4650	4500	3700	2500	2050	-	2985	1308	1309	1077	-	1514	2392	1191	973