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EXHAUST EMISSIONS FROM UNCONTROLLED VEHICLES AND RELATED EQUIPMENT USING INTERNAL COMBUSTION ENGINES

PART 5: FARM, CONSTRUCTION, AND INDUSTRIAL ENGINES

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

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Contract No. EHS-70-108

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
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ABSTRACT

This report is part 5 of the Final Report on Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines, Contract EHS 70-108. The engine categories covered in this report are heavy-duty gasoline and diesel engines used in farm, construction, and industrial applications. Exhaust emissions from twelve engines were measured, including eight diesels and four gasoline engines.

The four gasoline engines were a Ford G5000, a Hercules G-2300, a J. I. Case 159G, and a Wisconsin VH4D. The eight diesel engines tested were an Allis-Chalmers 3500, a Caterpillar D6C, a Detroit Diesel 6V-71, an International D407, a John Deere 6404, a Mercedes-Benz OM636, an Onan DJBA, and a Perkins 4.236. The engines were tested using well-accepted steady-state procedures for gaseous emissions measurement, and in addition, the Federal procedure for smoke certification was used for testing the diesel engines (except the Onan). Some gaseous emissions were measured during transient operation of most of the engines, and particulate and smoke measurements were made during some of the same modes used for gaseous emissions sampling.

The analysis techniques which were used included FIA for total hydrocarbons; NDIR for CO, CO_2, and NO; chemiluminescence for NO and NO_x; electrochemical analysis for O_2; gas chromatograph for light hydrocarbons; the MBTH method for total aliphatic aldehydes (RCHO) and the chromotropic acid method for formaldehyde (HCHO); an experimental dilution-type sampling device for particulate; and the PHS full-flow smokemeter for smoke (diesels only). Hydrocarbons were also measured by NDIR for tests on the gasoline engines, and the FIA was heated to 160°F for tests on gasoline engines, but to about 360°F for diesel engine tests.

The twelve engines were operated on eddy-current stationary dynamometers, the largest of which had provision for the extra inertia required for Federal smoke tests. One of the dynamometers had motoring capability for closed-throttle modes on gasoline engines, so the three larger gasoline-fueled units were operated on this dynamometer. The emissions results obtained in this study, as well as data obtained from other sources, were used in conjunction with information on engine population and usage to estimate emission factors. Estimates of emission factors were made using emissions data developed on as broad a range of engines as possible, taking into account that several of the engines tested under this contract (as well as others on the market) are widely used in more than one of the three areas of application treated in this report (farm, construction, and industrial). National impact was estimated separately for each of the three engine applications, based on population and usage information developed independently for each application.

FOREWORD

The project for which this report constitutes part of the end product was initiated jointly on June 29, 1970, by the Division of Motor Vehicle Research and Development and the Division of Air Quality and Emission Data, both divisions of the agency known as NAPCA. Currently, these offices are the Emission Characterization and Control Development Branch of the Office of Mobile Source Air Pollution Control, and the National Air Data Branch of the Office of Air Quality Planning and Standards, respectively. Both offices are within the Office of Air and Water Programs, Environmental Protection Agency. The subject contract number is EHS 70-108, and the project is identified within Southwest Research Institute as 11-2869-001.

This report (Part 5) covers the heavy-duty farm, construction, and industrial engine portion of the characterization work only; and the six other items in the characterization work have been or will be covered by six other parts of the final report. In the order in which the final reports have been or will be submitted, the seven parts of the characterization work include: Locomotives and Marine Counterparts; Outboard Motors; Motorcycles; Small Utility Engines; Farm, Construction, and Industrial Engines; Gas Turbine "Peaking" Power Plants and Snowmobiles. Other efforts which have been conducted as separate phases of Contract EHS 70-108 include: measurement of gaseous emissions from a number of aircraft turbine engines; measurement of crankcase drainage from a number of outboard motors; and investigation of emissions control technology for locomotive diesel engines; and those phases either have been or will be reported separately.

Cognizant technical personnel for the Environmental Protection Agency are currently Messrs. William Rogers Oliver and David S. Kircher, and past Project Officers include Messrs. J. L. Raney, A. J. Hoffman, B. D. McNutt, and G. J. Kennedy. Project Manager for Southwest Research Institute has been Mr. Karl J. Springer, and Mr. Charles T. Hare has carried the technical responsibility.

The offices of the sponsoring agency (EPA) are located at 2565 Plymouth Road, Ann Arbor, Michigan 48105 and at Research Triangle Park, North Carolina 27711. The contractor (SwRI) is located at 8500 Culebra Road, San Antonio, Texas 78284.

The assistance of several corporations, groups, and individuals has contributed materially to the success of the farm, construction, and industrial engine portion of this project. Appreciation is expressed to: Allis-Chalmers (Mr. William Hamilton); Caterpillar Tractor Co. (Mr. Don Henderson and Mr. Duane E. Evans); Detroit Diesel Allison Division, General Motors Corp. (Mr. David F. Merrion and Mr. John W. Caradonna);

The General Motors Environmental Activities Staff (Mr. George Hanley); Ford Tractor Operations (Mr. John H. Zich); Hercules Engine Division, White Engines, Inc. (Mr. Robert L. Bodnar); International Harvester Company (Mr. Charles R. Hudson); J. I. Case Co. (Mr. Don Shelton and Mr. John Crowley); John Deere (Mr. Robert Parker); Mercedes-Benz of North America, Inc. (Mr. Gerhard Langhans and Mr. K. H. Faber); Onan (Mr. J. C. Hoiby); Perkins Engines, Inc. (Mr. Neville Hartwell); and Teledyne Wisconsin Motor (Mr. John A. Gresch).

Thanks are also expressed to the OAP Emissions Survey Subcommittee of the Emissions Standards Committee, Engine Manufacturers Association. This group is composed largely of the gentlemen listed above (with their company affiliations), and it contributed a great deal in recommending engines to be tested and in supplying other technical information on usage and duty cycles. Until recently, the chairman of this subcommittee was Mr. John Crowley, and his substantial efforts over a period of more than two years are very much appreciated.

The SwRI personnel involved in the farm, construction, and industrial engine tests included Russel T. Mack, lead technician; Joyce McBryde and Joyce Winfield, laboratory assistants; and Orville Davis, William P. Jack, Ernest Krueger, and Nathan Reeh, technicians. These people all made major contributions to the research effort which are sincerely appreciated.

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I. INTRODUCTION

The program of research on which this report is based was initiated by the Environmental Protection Agency to (1) characterize emissions from a broad range of internal combustion engines in order to accurately set priorities for future control, as required, and (2) assist in developing more inclusive national and regional air pollution inventories. This document, which is Part 5 of what is planned to be a seven-part final report, concerns emissions from farm, construction, and industrial engines and the national impact of these emissions.

Emissions data on some of the engines considered to be important to the heavy-duty farm, construction, and industrial engine categories have been developed outside the subject contract, and where possible these data will be considered in developing emission factors. Although the procedures used to acquire data in the subject program were related to those used (or proposed) for emissions certification, it should be noted that they were used in this project for research purposes only. No consideration has been given to the potential usefulness of the procedures used for anything except research purposes.

The testing portion of the work on farm, construction, and industrial engines began about February 1, 1972, and extended until about February 1, 1973. The engines tested, then, were representative of production prior to testing dates, and may not have incorporated all the latest emission control technology. This extended test period reflects the scheduling of numerous other tests during the same time period, including both those applying to the subject contract (outboards, motorcycles, locomotives, etc.) and some applying to other contracts. All the tests were performed in the SwRI Emissions Research Laboratory.

II. OBJECTIVES

The objectives of the heavy-duty farm, construction, and industrial engine part of this project were to obtain emissions data on a variety of engines, and to use these and other available emissions data in conjunction with information on engine population and usage to estimate emission factors and national impact. The emissions to be measured for all the engines included hydrocarbons by FIA; CO, CO_2, and NO by NDIR: NO and NO_x by chemiluminescence; O_2 by electrochemical analysis; light hydrocarbons by gas chromatograph; aldehydes by wet chemistry; and particulate by gravimetric analysis. In addition, hydrocarbons were to'be measured by NDIR for gasoline engines, and smoke by the PHS full-flow smokemeter for diesel engines. These emission measurements are essentially the same as those made on all the other categories of engines tested under this contract.

Emission measurement procedures for engines similar to those tested (but for highway applications only) had already been given a great deal of consideration when the subject tests began, so it was not necessary to develop procedures from scratch. It became a secondary objective, however, to determine how the on-highway procedures should be modified (if, indeed, they should be modified at all) to better represent off-highway applications of the engines tested.

III. TEST DOCUMENTATION, INSTRUMENTATION, AND PROCEDURES

This section of the report includes descriptions and photographs of the test engines, descriptions and photographs of the instrumentation systems used, and explanations of the test sequences and calculation methods employed. In brief, the engines were chosen to be as representative as possible of those used in the field, but no attempt was made to use a national probability sample or any similarly structured group due to the extremely small number of engines to be tested. The test procedures used for gaseous emissions were similar to the "Federal 13-mode" test[1] or the "EMA-California 13-mode" test[2], except that some of them had 21 modes (diesel) or 23 modes (gasoline). The instrumentation used was representative of state-of-the-art practice, although occasional instrument downtime did prevent the acquisition of some data during a few runs.

A. Engine Specifications and Descriptions

In order to show the extent to which available diesel and gasoline engines for F, C, & I (farm, construction, and industrial) applications were represented by those chosen for testing under this contract, the major specifications of the test engines have been assembled to form Table 1. Power outputs ranged from under 15 hp to over 200 hp for diesels (almost 300 hp if it is assumed that the 6V-71 is representing an 8V-71), and from 30 hp to about 85 hp for spark-ignition engines. In major design features, the gasoline engines were similar to each other except for the air cooling and "Vee" block design of the Wisconsin VH4D. In contrast, the diesel engines were of a variety of types. The single 2-stroke engine tested had open combustion chambers and used blower scavenging; and the 4-stroke engines included turbocharged models with both open and precombustion chambers, and naturally aspirated models with both open and precombustion chambers. In addition, one of the two naturally aspirated 4-stroke engines with prechambers was air cooled, while the other was water cooled. It should be noted that the test engines were representative of production prior to 1972 models (generally), and that they may not have incorporated the latest in emission control technology. The engines were supplied on loan by their manufacturers, and were assumed to be correctly adjusted and ready to operate unless their performance indicated otherwise.

The primary applications of the engines tested are distributed quite evenly among the farm, construction, and industrial categories. This distribution holds within the diesel group and within the gasoline group as well as the entire sample of engines. It is also obvious that an effort was made to test products of as many different manufacturers as possible, since no two test engines were made by the same company.

TABLE 1. SPECIFICATIONS OF TEST ENGINES

Diesel

Mfr. & Model	AC 3500	Cat D6C	D D 6V-71	Int D407
displacement, in^3	426	638	426	407
cyls. (arrangement-no.)	I-6	I-6	V-6	I-6
cycle	4-stroke	4-stroke	2-stroke	4-stroke
aspiration	Turbo	Turbo	Blower	Natural
comb. chamber	open	pre-cup	open	open
rated hp @ rpm	157 @ 2200	149 @ 1900*	208 @ 2100*	112 @ 2400
rated torque (ft lb_f) @ rpm	438 @ 1700*	486 @ 1400*	557 @ 1600*	274 @ 1800*
cooling medium	water	water	water	water
weight, lb_f	1300*	2000*	1960*	approx. 1600*
injection system	Simm's pump	own-pump	own-unit	Roosa-pump

Diesel

Mfr. & Model	J D 6404	M-B OM636	Onan DJBA	Per 4.236
displacement, in^3	404	108	60	236
cyls. (arrangement-no.)	I-6	I-4	I-2	I-4
cycle	4-stroke	4-stroke	4-stroke	4-stroke
aspiration	Turbo	Natural	Natural	Natural
comb. chamber	open	pre-cup	pre-cup	open
rated hp @ rpm	129 @ 2200	29 @ 2400	14.6 @ 2400	80 @ 2500
rated torque (ft lb_f) @ rpm	340 @ 1500	60 @ 2000	36 @ 1800	197 @ 1300
cooling medium	water	water	air	water
weight, lb_f	approx. 1500*	388	270	596
injection system	Roosa-pump	Bosch-pump	Bosch-pump	C.A.V.-pump

Gasoline

Mfr. & Model	Ford G5000	Herc. G-2300	J I Case 159G	Wisc VH4D
displacement, in^3	256	226	159	108
cyls. (arrangement-no.)	I-4	I-4	I-4	V-4
rated hp @ rpm	71 @ 2100	84.5 @ 2400	48 @ 2100	30 @ 2800
rated torque (ft lb_f) @ rpm	206 @ 1100	205 @ 1400	131 @ 1200	66 @ 1700
cooling medium	water	water	water	air
weight, lb_f	860	590	approx. 600*	310
carburetion	1V updraft	1V updraft	1V updraft	1V updraft

* measured or otherwise acquired, but not from mfr's. data

To provide better visualization of the test engines, photographs of them appear as Figures 1 through 12. These photos also show some of the mechanical equipment and exhaust systems, as well as air and fuel flow measuring instrumentation.

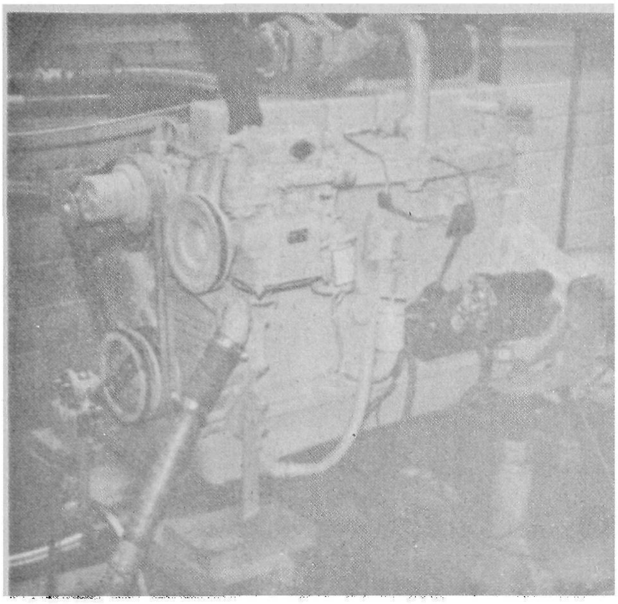

Figure 1. Allis-Chalmers 3500 Diesel- Engine

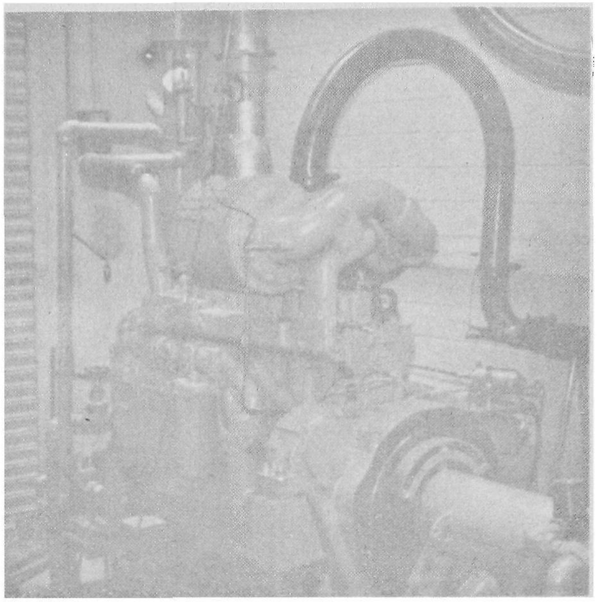

Figure 2. Caterpillar D6C Diesel Engine

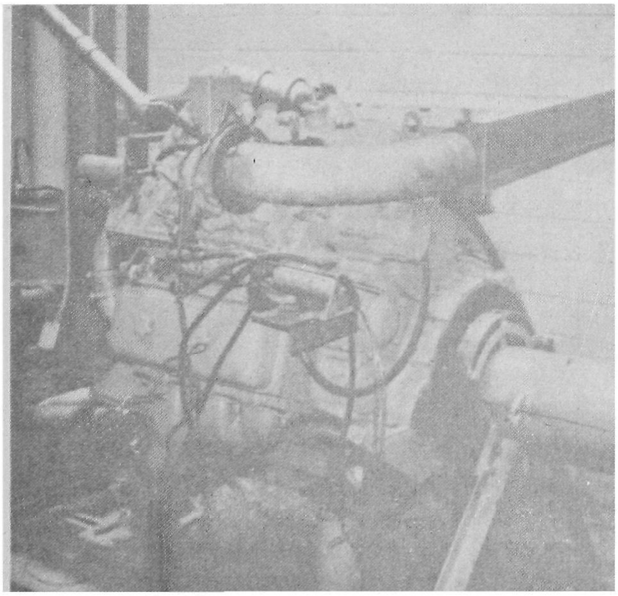

Figure 3. Detroit Diesel 6V-71 Diesel Engine

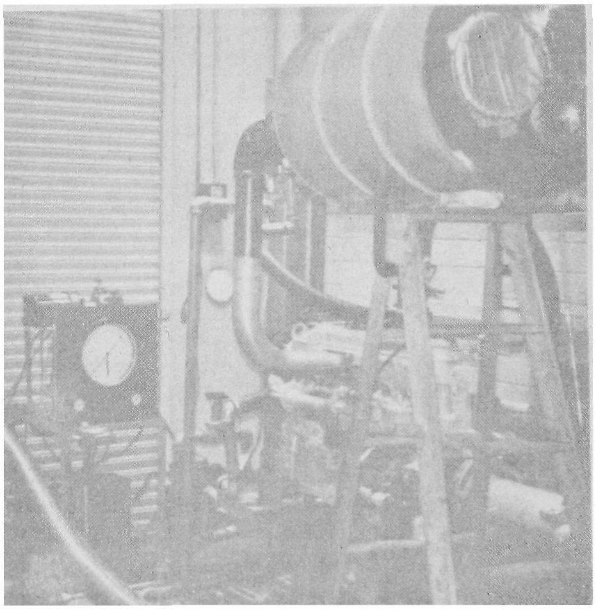

Figure 4. International Harvester D407 Diesel Engine

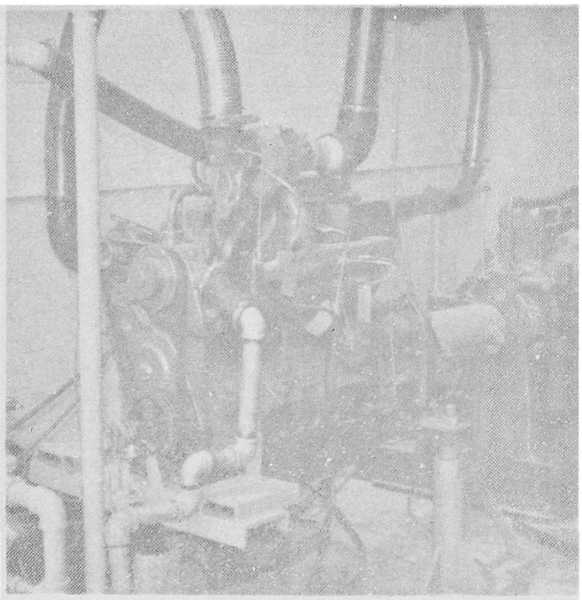

Figure 5. John Deere 6404 Diesel Engine

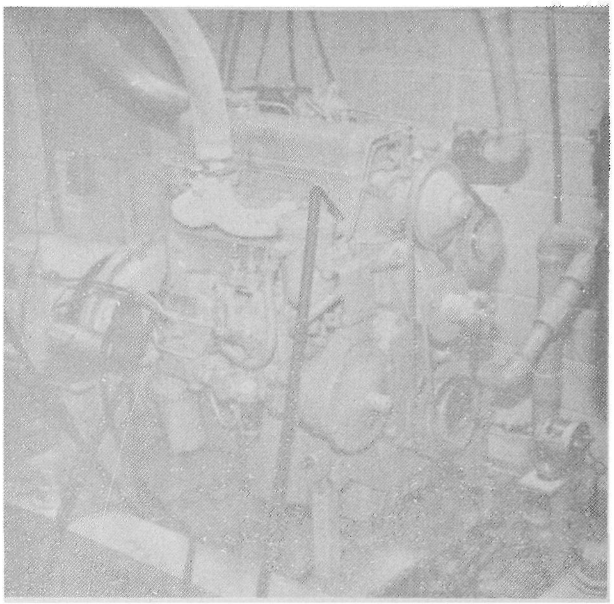

Figure 6. Mercedes-Benz OM636 Diesel Engine

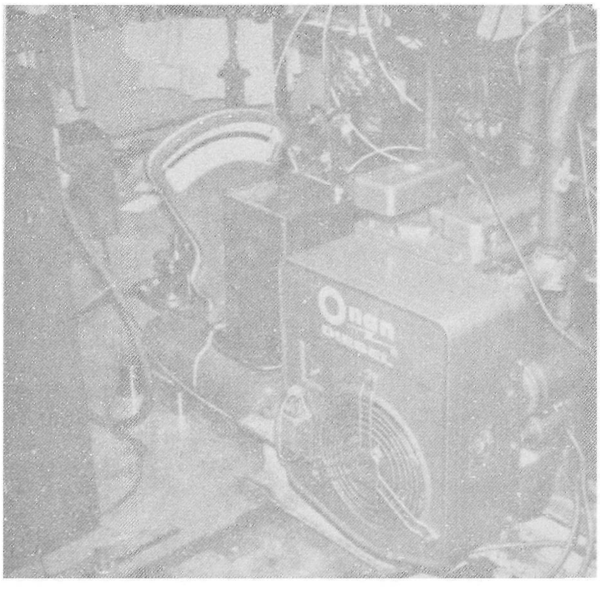

Figure 7. Onan DJBA Diesel Engine

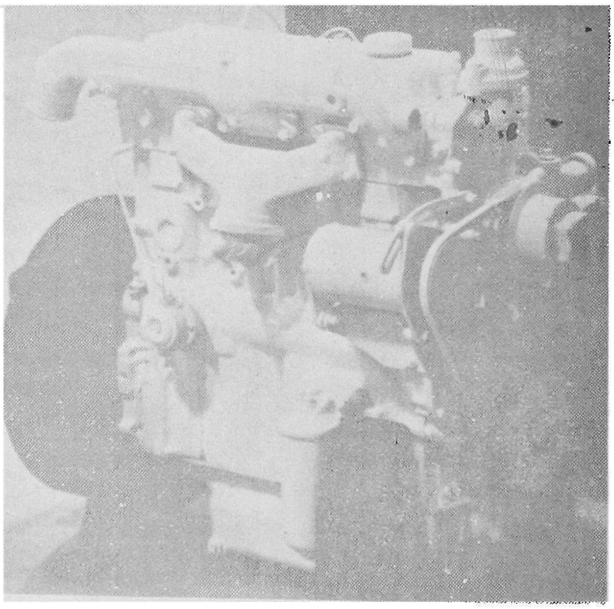

Figure 8. Perkins 4.236 Diesel Engine

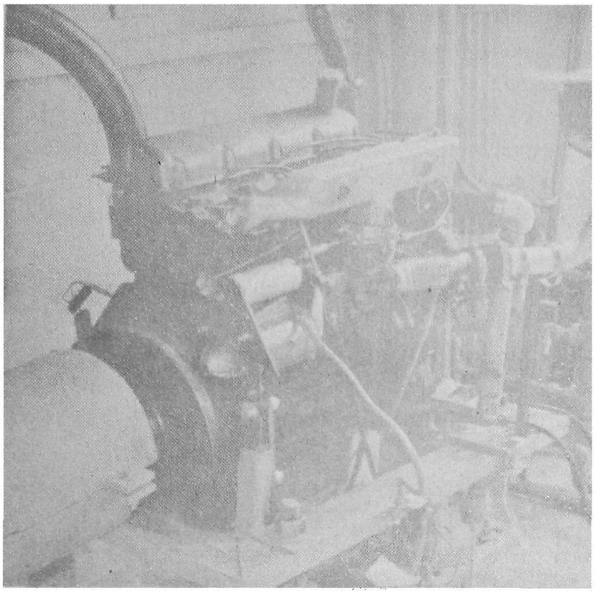

Figure 9. Ford G5000 Gasoline Engine

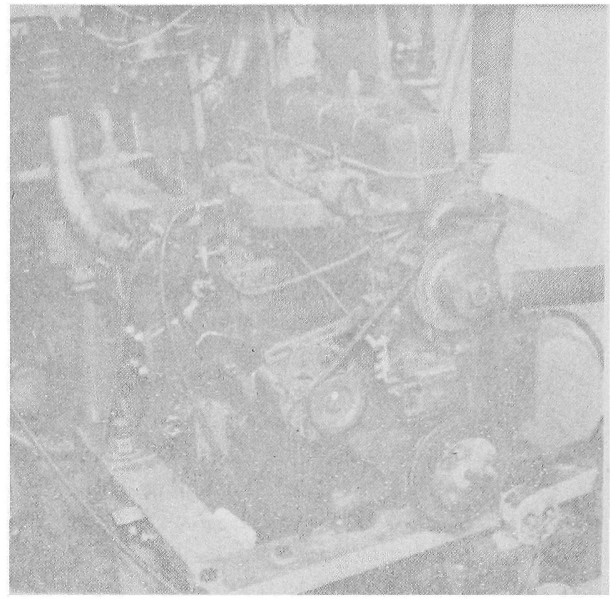

Figure 10. Hercules G-2300 Gasoline Engine

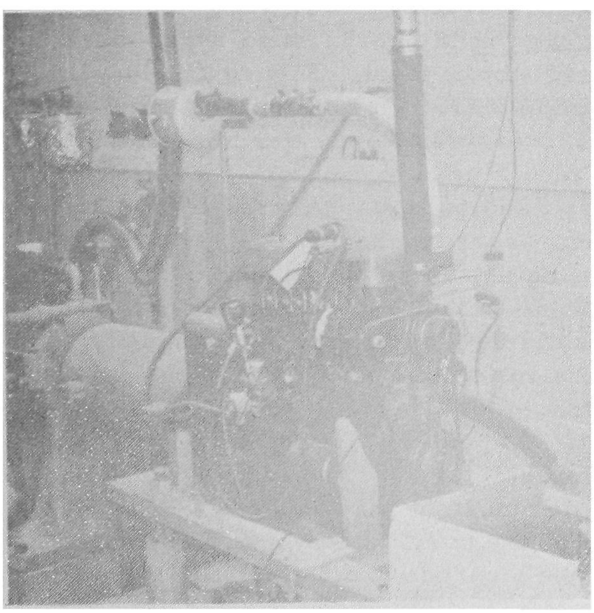

Figure 11. J. I. Case 159G Gasoline Engine

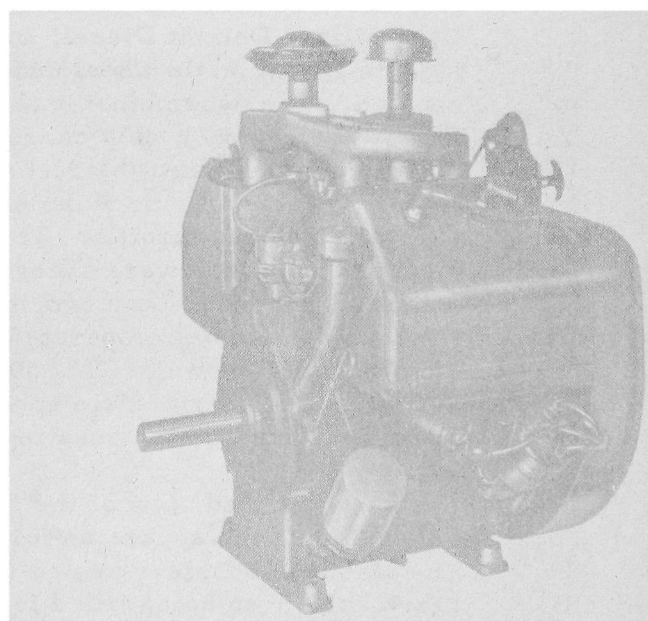

Figure 12. Wisconsin VH4D Gasoline Engine (Photo Supplied by Teledyne-Wisconsin Motor)

B. Instrumentation and Measurement Techniques

The types of instrumentation used for measuring emissions during tests on the F, C, & I engines have already been mentioned, but in this section they will be described in more detail. The nondispersive infrared analyzers used for measurement of CO, CO_2, and NO (plus hydrocarbons for gasoline engines) were Beckman 315A's and 315B's, and the electrochemical oxygen analyzer was a Beckman model 715. For tests on the four gasoline engines and on the Onan DJBA, the chemiluminescent NO_x analyzer used was a Thermo-Electron unit. For tests on the other diesel engines, the chemiluminescent instrument used was one of several fabricated by SwRI for use in the Emissions Research Laboratory. The flame ionization analyzers used for total hydrocarbon measurements during all the tests were units fabricated in and for the Emissions Research Laboratory. These FIA units have temperature capability from room temperature to 400°F, and they use positive-pressure detectors and Keithley 417K chromatograph electrometers. Readout for all the instruments except NDIR NO, O_2, and NDIR hydrocarbons (when used) was provided by either a Texas Instruments 4-pen or a Rikadenki 6-pen recorder.

The instrumentation package used for gaseous emissions measurements on all the diesel engine tests except those on the Onan DJBA is shown in Figure 13, and the package used for the remaining tests is shown in Figure 14. Figure 15 shows the 500 hp-capacity eddy current dynamometer used for tests on the larger diesel engines (Allis-Chalmers, Caterpillar, Detroit Diesel, International Harvester, and John Deere), including the inertia wheel under the guard in the background which was coupled to the dynamometer for Federal smoke tests. Figure 16 shows the 250-hp capacity eddy current dynamometer used for testing of the other water-cooled engines (Mercedes-Benz, Perkins, Ford, Hercules, and J. I. Case), including the 50 hp electric motor used to "motor" the gasoline engines at closed throttle. The gearbelt and pulleys, covered by a guard when in operation, were changed as necessary to provide the required crankshaft speeds. The two smallest engines were air-cooled (Onan and Wisconsin), and were operated on a 50 hp-capacity eddy current dynamometer (not shown). This 50 hp unit did not have motoring capability, so the rated and intermediate speed modes run at closed throttle were deleted from the Wisconsin's operating schedule.

A detailed view of the FIA oven/detector assembly is shown in Figure 17, including the apparatus for aldehyde and light hydrocarbon sampling. The aldehyde bubblers are on the side of the oven, and a bag is shown at the rear of the oven being filled for light hydrocarbon analysis. The methods employed for batch sampling were the MBTH method[3] for total aliphatic aldehydes (RCHO) and the chromotropic acid method[4] for formaldehyde (HCHO). The chromatograph employed for light hydrocarbon analysis used

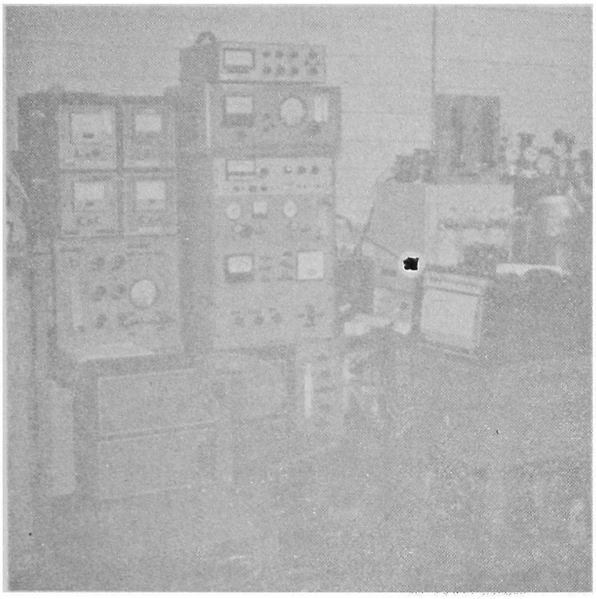

Figure 13. Instrumentation Used for Measurement of Gaseous Emissions from Diesel Engines

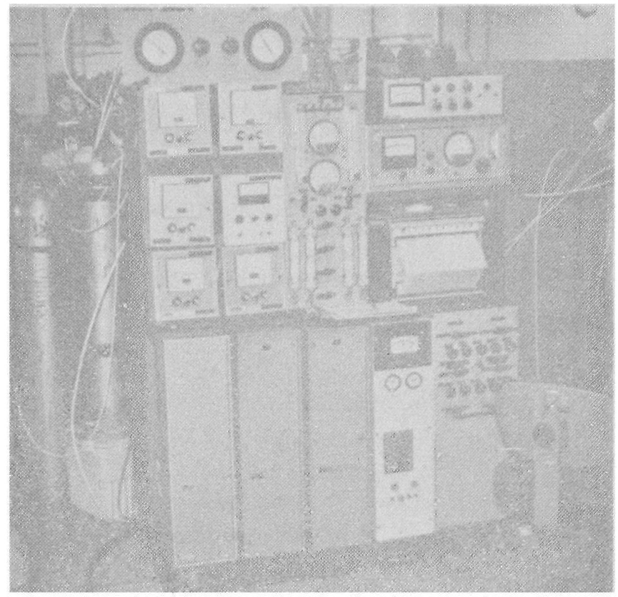

Figure 14. Instrumentation Used for Measurement of Gaseous Emissions from Gasoline Engines

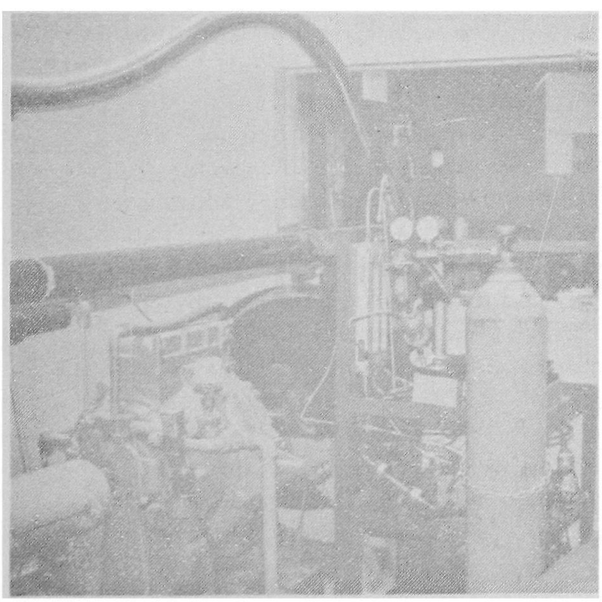

Figure 15. 500-hp Capacity Eddy-Current Dynamometer Used for Tests of Large Diesel Engines

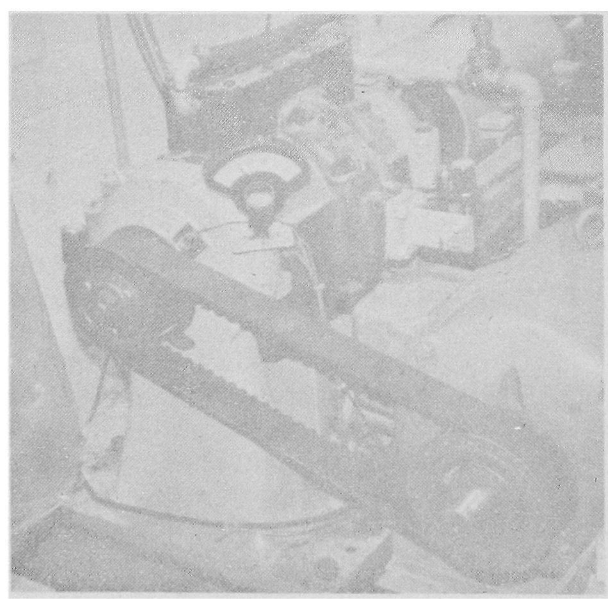

Figure 16. 250-hp Capacity Eddy-Current Dynamometer Used for Tests of Smaller Engines

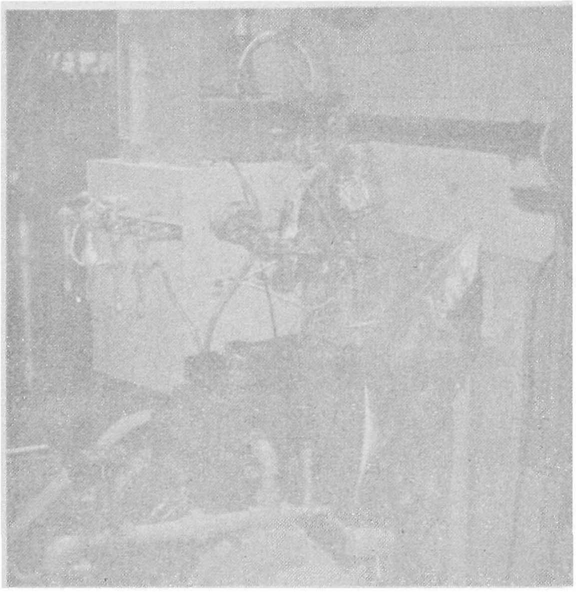

Figure 17. FIA Oven/Detector Unit Used for Hydrocarbon Analysis

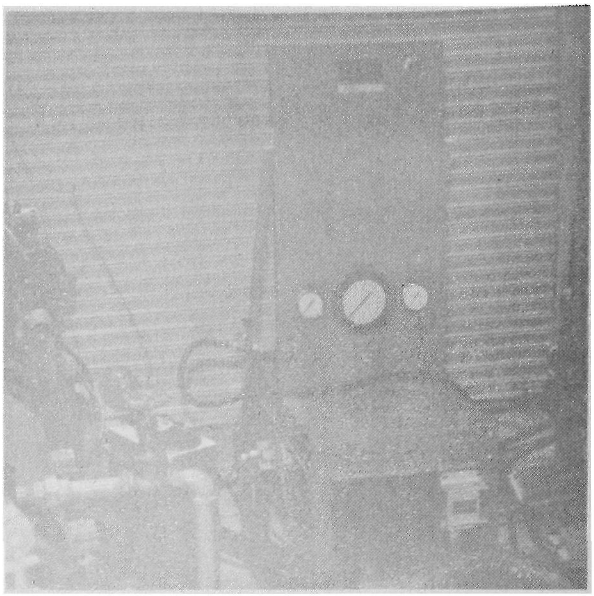

Figure 18. Flo-Tron Fuel Flow Measurement Device of the Type Used During Most Emissions Tests

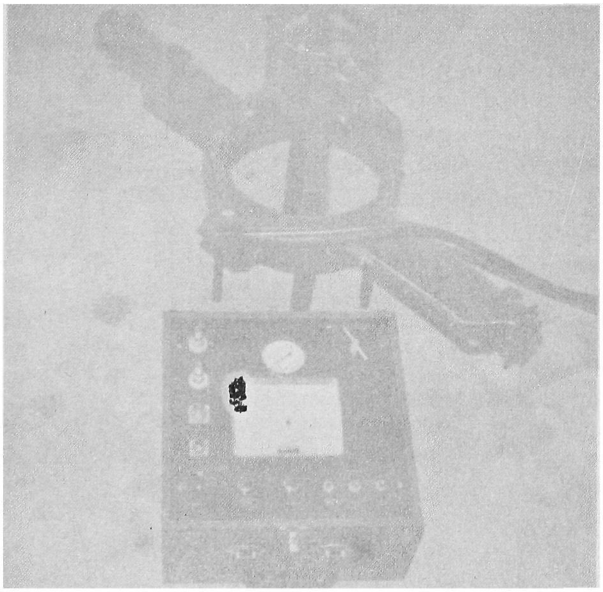

Figure 19. PHS Light Extinction Smokemeter

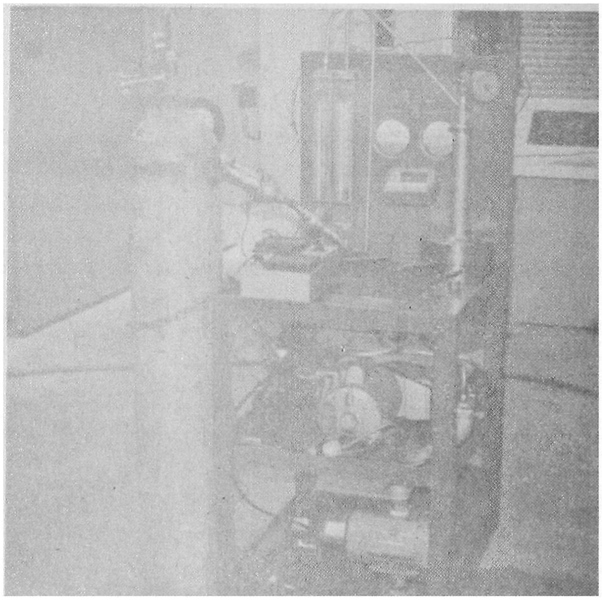

Figure 20. Experimental Dilution-Type Particulate Sampler

a 10 ft by 1/8 inch column packed with a mixture of phenyl isocyanate and Porasil C, and a 1 inch by 1/8 inch precolumn packed with 100-120 mesh Porapak N. This chromatograph analysis was sensitive to seven compounds (methane through butane), although in many cases one or more of the seven compounds was not present in measureable amounts.

Figure 18 shows one of three Flo-tron fuel mass flow measuring devices which were employed during the subject tests (another is shown in Figure 4 with the International Harvester D407 engine). These devices were used for tests on most of the engines, and a weight-time system (using a scale and stopwatch) was used for the remaining tests. Air flow measurements on all the diesel engines except the Detroit Diesel and the Onan were taken using one or a combination of the long radius nozzles mounted in the plenum shown in Figure 4. Air flow to the Detroit Diesel was measured with a laminar flow element, and no air flow data were acquired on the Onan.

Smoke measurements on the diesel engines were made using a PHS light extinction smokemeter such as the one shown in Figure 19. This instrument, or a substantial equivalent, is required by Federal law for smoke certification(1), and in all cases readout was provided by a strip chart recorder. Exhaust particulate was measured under steady-state conditions by the experimental dilution-type sampling device shown in Figure 20. This device was developed to meet the objective of measuring particulate at atmospheric pressure and 85°F, and it uses primary filters having a mean flow pore size of 0.45 micron (1.77×10^{-5}in). The sampler has continuous flow indication which permits adjustment of the sample rate within ± 2% of the desired value, and this rate is set as near isokinetic as possible. It is recognized, however, that the best the system can do is to match probe entrance velocity to exhaust bulk velocity, rather than match the instantaneous velocity vector as required for true isokinetic sampling. The hot exhaust sample is cooled and diluted by a known flow of prepurified dry compressed air (metered via a critical orifice) before being filtered, then mixed flow is totalized by a Rootsmeter. Total exhaust sample flow over the sampling period (5 to 10 minutes) is determined by subtracting the dilution gas flow from the total (mixed) flow. Filters are preweighed (clean) and then weighed after use (a minimum of four independent weighings both before and after) in a humidity-controlled environment, and the final two weights must be within 0.2 mg of each other. Particulate amounts collected during tests on the F, C, & I engines ranged from about 10 mg to over 100 mg, and the electronic balance used to weigh the filters had an accuracy of ± 0.1 mg.

C. Emissions Test Procedures and Fuel Specifications

Nearly all the gaseous and particulate emissions tests conducted on the F, C, & I engines were composed of a number of steady-state conditions run in a prescribed sequence. In these steady-state procedures, no attempt was made to compute emissions during transients (while engine load and/or speed were changing). The test procedures are all based on the EMA-California ARB 13-mode procedure[2] with variations to accomodate the needs of the subject program. A few additional runs were made with continuous readouts of engine rpm, HC, CO, and NO_x, to determine whether emissions during transients were sufficiently different from emissions during steady-state operation to warrant their inclusion in calculations leading to emission factors. It was found that excursions of emission values beyond normal limits did occur in some cases, but that these excursions did not combine in magnitude and duration to make any significant change in the overall emissions picture.

The only other tests involving transients were the Federal smoke tests on the diesel engines, which are composed almost solely of accelerations and lug-downs[1]. The steady-state gaseous emissions test procedures used for diesels had either 21 or 13 modes, and those used for gasoline engines had either 23 or 13 modes (the 13-mode tests were identical for diesel and gasoline engines). These procedures are described in Table 2, which gives engine speed and percent of full load at that speed by mode. The notes following Table 2, especially (c), are important to prevent confusion when referring to Appendixes F and G for data on the gasoline engines. To elaborate on the point made in note (c), the computer program used to calculate brake specific emissions required mode data in the order shown in Table 2. It is obvious from inspection of Figure 16 that the engine and dynamometer had to be stopped to change closed-throttle "motoring" speeds, because belts and pulleys were removed and replaced to accomplish speed changes. Therefore, the test sequence could not be run in the order required for computer input without mid-test shutdowns, and it was decided to defer the closed-throttle modes until the remainder of the tests had been conducted. The belt connecting the dynamometer to the electric motor was removed for all the non-motored conditions to prevent possible frictional losses.

Reiterating another point made earlier, no closed-throttle "motoring" data were acquired on the Wisconsin VH4D engine because it was operated on a smaller dynamometer which did not have motoring capability. Absence of the closed-throttle data also made it impractical to obtain composite brake specific emissions on the Wisconsin by computer, so no computer data appear for this engine in Appendix G.

The 13-mode procedures (performed in addition to 21- or 23-mode tests, and at different speeds) were run to provide a better basis for "mapping" emissions from the test engines according to speed and load, and thus they were termed "mapping runs" and given designations such as M-1, M-2, and so on. At least two 13-mode runs were made on each engine except the Caterpillar D6C, the exception being made because this engine's assumed operating speed range was very narrow (1400 to 1900 rpm) and because its emissions were observed not to vary significantly

TABLE 2. DESCRIPTION OF STEADY-STATE GASEOUS EMISSIONS TEST PROCEDURES

	21-Mode (Diesel)		13-Mode (Gasoline and Diesel)		23-Mode (Gasoline)	
Mode	Engine rpm	Load %	Engine rpm	Load %	Engine rpm	Load %
1	Low Idle	0	Low Idle	00	Low Idle	0
2	Intermediate	0	Speed No. 3[a]	00	Intermediate	0
3	Intermediate	12.5	Speed No. 3[a]	25	Intermediate	12.5
4	Intermediate	25	Speed No. 3[a]	50	Intermediate	25
5	Intermediate	37.5	Speed No. 3[a]	75	Intermediate	37.5
6	Intermediate	50	Speed No. 3[a]	100	Intermediate	50
7	Intermediate	62.5	Low Idle	0	Intermediate	62.5
8	Intermediate	75	Speed No. 4[b]	100	Intermediate	75
9	Intermediate	87.5	Speed No. 4[b]	75	Intermediate	87.5
10	Intermediate	100	Speed No. 4[b]	50	Intermediate	100
11	Low Idle	0	Speed No. 4[b]	25	Low Idle	0
12	Rated	100	Speed No. 4[b]	0	Intermediate	CT[c]
13	Rated	87.5	Low Idle	0	Rated	100
14	Rated	75	---	--	Rated	87.5
15	Rated	62.5	---	--	Rated	75
16	Rated	50	---	--	Rated	62.5
17	Rated	37.5	---	--	Rated	50
18	Rated	25	---	--	Rated	37.5
19	Rated	12.5	---	--	Rated	25
20	Rated	0	---	--	Rated	12.5
21	Low Idle	0	---	--	Rated	0
22	---	--	---	--	Low Idle	0
23	---	--	---	--	Rated	CT

Notes: (a) rpm lower than Speed No. 4, either above or below Intermediate, as needed.

(b) rpm between Rated and Intermediate, generally closer to Rated than Intermediate

(c) CT means "Closed Throttle" or "motored" conditions the order of conditions shown was used for computer setup only (Appendixes D and G) - actual run sequence and tabular data (Appendixes C and F) had non-motored Rated speed modes as 12-20, followed in order by Low idle, Intermediate CT, and Rated CT with operating speed (see Figures A-2, A-10, and A-18 in Appendix A). These 13-mode tests were run using Speed No. 3 in place of Intermediate, and Speed No. 4 in place of Rated, as shown in Tables 2 and 3. Note that speed No. 3 was chosen below normal intermediate for the 6V-71 and the Onan because they were assumed to have some applications utilizing these lower speeds.

The speeds chosen as "rated" and "intermediate" were manufacturer's rated speed, and either peak torque speed or 60% of rated speed (whichever was higher), respectively. For convenience, the operating speeds used for test purposes are summarized in Table 3. This information in conjunction with that in Table 2 yields full descriptions of all the steady-state operating conditions used for measurement of gaseous emissions. Particulate measurements were generally conducted at seven steady-state conditions only, due to their large time requirements. These conditions were; low idle; 100%, 50%, and zero load at intermediate speed; and 100%, 50%, and zero load at rated speed. Each particulate condition was repeated several

TABLE 3. OPERATING SPEEDS USED DURING EMISSIONS TESTS

Engine	Engine rpm at Condition				
	Intermediate	Rated	Speed No. 3	Speed No. 4	Low Idle
Allis-Chalmers 3500	1500	2200	1700	2000	800
Caterpillar D6C	1400	1900	-	-	640
Detroit Diesel 6V-71	1600	2100	1200	1800	440
International Harvester D407	1800	2500	2100	2300	700
John Deere 6404	1500	2200	1700	1900	800
Mercedes-Benz OM636	1400	2400	1700	2100	700
Onan DJBA	1800	2400	1500	2100	*1500
Perkins 4.236	1450	2400	1700	2100	620
Ford G5000	1400	2100	1600	1900	660
Hercules G-2300	1450	2400	1750	2100	600
J. I. Case 159G	1400	2100	1600	1900	490
Wisconsin VH4D	1700	2800	2000	2400	920

*Minimum ungoverned speed - governed 1000 rpm idle used for two of the four 13-mode runs conducted

times to check on the repeatability of the results, and to provide reasonably accurate averages. The gaseous emissions acquired by batch sampling, namely aldehydes and light hydrocarbons (by gas chromatograph), were measured at 25% power increments during the 21-mode and 23-mode runs only. In addition, these batch-sampled emissions were also measured during the motored closed-throttle conditions on the Ford G5000 and Hercules G-2300 engines (modes 12 and 23 of the 23-mode procedure shown in Table 2).

Computation of mass-based emissions by mode from concentration data, fuel flow, and (in some cases) air flow was performed by one of two techniques. The first method was substantially equivalent to that outlined in the EMA-California ARB 13-mode diesel emissions measurement procedure, using the following basic equations for each mode. The third equation was originally written in terms of NO rather than NO_x, but otherwise they are the same as the original ones. The NO_x concentration

grams HC per hour = 0.0132 (ppmC) (exhaust flow, lb_m/min)
grams CO per hour = 0.0263 (ppm CO) (exhaust flow, lb_m/min)
grams NO_x (as NO_2) per hour = 0.0432 (ppm NO_x) (exhaust flow, lb_m/min)

in the third equation was that obtained from the chemiluminescent analyzer. These equations were used in the computer program to generate mass emissions data on all the diesel engines except the Onan DJBA, for which no air flow data were taken. They were also used to generate the tabular data given in Appendix C for the Caterpillar, International Harvester, and John Deere engines. Brake specific emissions data by mode were obtained by simply dividing the mass emissions results by power output. All exhaust flow and concentration data used in these equations, as well as throughout the remainder of this report, are on a "wet" basis. The computer data (Appendixes D and G) have been corrected for removal of combustion water only, but all the other data have been corrected for removal of atmospheric moisture as well.

The assumptions inherent in the three conversion equations above are that (1) the molecular weight of the exhaust gases is the same as that of air (28.97), and (2) the atomic hydrogen/carbon ratio of the exhaust hydrocarbons is 2.00. In a later section of the report, mass emissions of aldehydes and particulate will be presented. They were computed using the following basic equations, which are consistent in assumptions with the three already given.

grams RCHO (as HCHO) per hour = 0.0282 (ppm RCHO) (exhaust flow, lb_m/min)
grams particulate per hour = 0.802 (particulate concentration, mg/SCF) (exhaust flow, lb_m/min)

The second method of computing mass emissions by mode from concentration data was a fuel-based technique, sometimes called the "carbon balance" method. The principal advantage of this method is that air flow measurement is not required, which helps to assure that emissions (especially from gasoline engines) are not being upset by the measurement process. The basic equation for conversion of hydrocarbon concentrations to mass emissions is the same for gasoline and diesel engine emissions, but the constants in the equations for the other constituents are not the same for gasoline and diesel engines. The following general equations apply to both gasoline and diesel emissions, providing that the

grams HC per hour = 0.0454 (ppmC) (fuel rate, lb_m/hr)/(total carbon)
grams CO per hour = K_{CO} (ppm CO) (fuel rate, lb_m/hr)/(total carbon)
grams NO_x (as NO_2) per hour = K_{NO_x} (ppm NO_x) (fuel rate, lb_m/hr)/(total carbon)
grams RCHO (as HCHO) per hour = K_{RCHO} (ppm RCHO) (fuel rate, lb_m/hr)/(total carbon)
grams particulate per hour = $K_{Part.}$ (particulate concentration, mg/SCF) (fuel rate, lb_m/hr)/(total carbon)

and total carbon = %HC (as C) + %CO +%CO_2

applicable constants are selected from Table 4.

TABLE 4. VALUES OF CONSTANTS IN "CARBON BALANCE" MASS EMISSION EQUATIONS

Constituent	Constant	Type of Fuel: Gasoline	Type of Fuel: Diesel
CO	K_{CO}	0.0916	0.0906
NO_x as NO_2	K_{NO_x}	0.150	0.149
RCHO as HCHO	K_{RCHO}	0.0982	0.0971
Particulate	$K_{Part.}$	2.79	2.76

The principal assumption inherent in this second computation method is that exhaust hydrocarbons have the same atomic hydrogen/carbon ratio as fuel hydrocarbons (1.85 for gasoline and 2.00 for diesel fuel). An additional assumption was made for calculation of particulate rate, namely that the exhaust molecular weight was equal to that of air. All the species concentrations used in the "carbon balance" equations were on a wet basis. This second set of equations, with constants as shown in Table 4, was used in the computer program to generate mass emissions data on all the gasoline engines <u>except</u> the Wisconsin. They were also used to calculate the tabular values in Appendix F for all the gasoline engines, and the tabular values in Appendix C for five diesels (Allis-Chalmers, Detroit Diesel, Mercedes-Benz, Onan, and Perkins). Computer runs were not made for the Onan and Wisconsin engines because in each case some required data were missing.

The initial computation of composite brake specific emissions on the F, C, & I engines was performed using mode weighting factors originally specified for on-highway engines. These factors for diesels were 0.20/3 = 0.0667 for idles, and 0.8/18 = 0.0444 for all the other modes. For gasoline engines, the factors were 0.20/3 = 0.0667 for idles, and 0.8/20 = 0.04 for all the other modes. Computation using these factors was a convenience, since the computer programs had incorporated them, but this use does not preclude the possibility of using <u>other</u> factors later in the report when emission factors and impact are calculated. Determination of reasonable mode weighting factors will be discussed in more detail for each application category following section IV (section V for farm engines, section VI for construction, and section VII for industrial engines).

Once mass emissions by mode have been determined by one of the methods outlined above, the definitions and equations below can be used to

M_i = individual mode emissions, g/hr
W_i = individual time-based mode weighting factor
hp_i = individual mode power, hp
n = number of modes (13, 21, or 23)

$$\text{cycle composite g/hr} = \sum_{i=1}^{n} M_i W_i$$

$$\text{cycle composite g/bhp hr} = \frac{\sum_{i=1}^{n} M_i W_i}{\sum_{i=1}^{n} hp_i W_i}$$

calculate cycle composite emissions based on whatever weighting factors are deemed appropriate for the particular application.

After the composite emissions were calculated for diesels, a "correction factor" taken from Federal regulations[1] was applied to the NO_x results, and it is shown below. The quantity "H" is humidity of intake air

$$\text{diesel } NO_x \text{ correction factor} = \frac{1}{1 - 0.0025\,(H-75)}$$

in grains water per pound dry air, and the equation is designed to revise NO_x emissions to the value which would have occurred had the humidity during the test been 75 grains water per pound dry air. Federal emissions regulations for gasoline engines include different correction factors for light-duty and heavy-duty engines, so it is not really clear which factor should be used for the F, C, and I engines. The computer results in Appendix G do not include a correction factor at all, nor do any data presented (for gasoline or diesel engines) on a mode-by-mode basis in either the Appendixes or the text. Only cycle composite NO_x emissions have been corrected to 75 grains humidity.

It would seem logical on the surface that the heavy-duty factor should be applied, since the F, C, & I engines are of the heavy-duty type, but consideration should be given to the derivation of this factor. The original work[5] shows derivation of the factor only on the basis of complete 9-mode Federal (heavy-duty) truck tests, using a set of mode weighting factors required through 1973. These weighting factors give a composite load factor between 0.45 and 0.5, whereas those which will become effective in 1974 yield a load factor between 0.2 and 0.25. On the other hand, the light-duty factor does not seem applicable to the test engines, because it applies to low-load factor road route operation.

Comparison of the HD and LD correction factors shows agreement within approximately 1% from 75 grains down to about 30 grains, but also a rapid divergence above 75 grains. At 101 grains, for instance (highest humidity recorded during gasoline engine tests), the LD factor is 1.139 and the HD factor only 1.068. In the absence of a humidity correction factor derived especially for the 23-mode procedure, a somewhat arbitrary decision must be made, and that decision is that the heavy-duty factor[1] (shown below) will be used. The data in Appendixes E, F, and G have not been

$$\text{gasoline } NO_x \text{ correction factor} = 0.634 = 0.00654\,H - 0.0000222\,H^2$$

corrected to 75 grains, nor have the mode data in the text, but the cycle composite results in the text have been corrected

Fuels used in performing tests on the F, C, & I engines met the requirements for emission test fuels as listed in Federal regulations(1). The diesel fuel used was number 2 grade, and the gasoline was a leaded type. Federal fuel requirements are listed in Table 5, along with typical specifications of the fuels used for testing. The hydrogen/carbon ratios of the fuels were not measured, but rather they were assumed when necessary to be 2.00 for diesel fuel and 1.85 for gasoline. These assumptions, as mentioned earlier in this section, are consistent with the practice used in formulating Federal calculation procedures.

D. Estimation of Unmeasured Emissions

A number of important exhaust constituents were measured during tests under the subject contract, but a few measurements of less important emissions had to be neglected due either to time and financial constraints or the lack of a reliable analysis method. Using these criteria, it was decided to estimate emissions of sulfur oxides (SO_x), evaporative hydrocarbons, and crankcase (blowby) hydrocarbons rather than attempt to measure them.

Taking the oxides of sulfur first, instrumentation for the measurement of this pollutant in raw exhaust has not been developed to the same

TABLE 5. FEDERAL EMISSIONS TEST FUEL REQUIREMENTS AND TYPICAL SPECIFICATIONS OF FUELS USED

	No. 2 Diesel Fuel			Gasoline	
Property	Federal Requirement	Typical Specification	Property	Federal (1973) Requirement	Typical Specification
Cetane	42-50	45.5	Octane, Res.	100 (Min)	102
IBP, °F	340-400	392	Lead, g/gal	3.1-3.3	3.2
10% pt., °F	400-460	439			
50% pt., °F	470-540	520	IBP, °F	75-95	90
90% pt., °F	550-610	582	10% pt., °F	120-135	126
EP, °F	580-660	648	50% pt., °F	200-230	216
			90% pt., °F	300-325	311
Gravity, °API	33-37	33.8	EP, °F	415 (Max)	360
Sulfur, %	0.2-0.5	0.32	Sulfur, %	0.10	0.01
Aromatics, %	27 (Min)	36.7	Phosphorus	0	0
Flash Point, °F	130 (Min)	180	RVP, psi	8.7-9.2	9.0
			Olefins, %	10 (Max)	0.6
Viscosity, cs.	2.0-3.2	2.5	Aromatics, %	35 (Max)	28.6

point as that for other common combustion products, so it has become more or less accepted practice to calculate sulfur oxide emissions based on fuel sulfur content. The assumption is usually made for convenience that all the sulfur oxidizes to SO_2, and thus the mass emission rate of SO_x is taken to be 2.00 times the rate at which sulfur is entering the engine in the fuel (2.00 is the ratio of the molecular weight of SO_2 to the atomic weight of S). This technique is fairly accurate for 4-stroke gasoline engines and all diesels, in which substantially all the fuel is burned. Emission rates will be calculated and included in section IV, based on assumed fuel sulfur contents of 0.043% by weight for gasoline and 0.22% for no. 2 diesel fuel[6].

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

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

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

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

Emissions from automobile crankcases have been controlled for some time by positive crankcase ventilation (PCV) systems, but there has been no general requirement for control of crankcase emissions from engines operated off-road. Consequently, most of the F, C, & I category heavy duty gasoline engines do not employ crankcase emission controls as standard equipment, although they are generally available as an option. Of the four gasoline engines tested under this part of the contract, only the Wisconsin employed a crankcase emission recirculating system.

Prior to legislation requiring PCV systems and other controls on automobiles, several studies were done to determine the amount and composition of crankcase emissions from 4-stroke gasoline engines[11, 12]. The best-supported generalization which can be derived from the results of these studies is that crankcase hydrocarbon emissions amount to about 20% of those in the exhaust, and that emission of other common pollutants is negligible. This estimate will be used to determine hydrocarbon emission factors for gasoline engines later in the report, with attempts to take into account fractions of production sold with and without control systems. The discussion on crankcase emissions applies only to gasoline engines, of course, since those from diesels are considered negligible.

IV. EMISSION TEST RESULTS

Most of the raw emissions data which form the basis for this section of the report are given in the Appendixes, with the exceptions of aldehyde, particulate, and light hydrocarbon concentrations, and steady-state smoke. The data not included in the Appendixes will be presented in this section of the text. Appendixes A through D provide data on the eight diesel engines tested, while Appendixes E through G do the same for the four gasoline engines tested.

The emission results are broken up into four subsections, with gaseous emissions first and particulate second. A subsection on smoke (from diesels only) follows, and the fourth division includes emission data contributed by manufacturers and that obtained from other sources outside the subject contract.

A. Results of Gaseous Emissions Tests

Complete basic gaseous emissions data (except aldehydes, light hydrocarbons, and particulate) are given in Appendix C for the diesel engines and in Appendix F for the gasoline engines. In addition, graphs showing emission concentrations (HC, CO, and NO_x only) as functions of load with speed as parameter are given in Appendix A for diesel engines and in Appendix E for gasoline engines. The data in Appendixes C and F can be used to assess repeatability, giving an indication of variation inherent in engine operation and the test procedures used.

This subsection contains concentration data on aldehydes and light hydrocarbons, as well as data on a mass basis and on a brake specific basis for the major gaseous pollutants (HC, CO, NO_x, aldehydes, and SO_x). The light hydrocarbon analysis was sensitive to seven compounds, from methane through butane, although in many instances not all the compounds were present in measurable amounts (0.1 ppm or more). The light hydrocarbon concentrations which will be given in this report are on a wet basis, and are expressed as ppm of the compound, not ppm C.

Table 6 gives light hydrocarbon data on the diesel engines tested, and only 5 compounds are shown because neither propane nor butane was found in any of the diesel exhaust samples. Table 7 presents corresponding data on the gasoline engines, but with all seven compounds represented. The data were taken during operation on the 21-mode procedure (diesels) or the 23-mode procedure (gasoline engines), at 25% power increments plus two idle modes and (in the case of the gasoline engines only) closed throttle modes.

The primary usage of the light hydrocarbon data would occur in attempting to describe the combustion processes taking place, but such an

TABLE 6. DATA ON LIGHT HYDROCARBON EMISSIONS FROM HEAVY-DUTY DIESEL ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

Condition		ppm Concentrations, A-C 3500 Engine					ppm Concentrations, Cat. D6-C Engine				
Speed	Load	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_6	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_6
Idle	0	15.	0.0	11.	0.0	0.0	0.0	0.0	7.9	3.3	2.3
Inter-	0	11.	0.0	10.	0.0	0.0	0.0	0.0	4.3	2.0	2.0
mediate	25%	9.4	0.0	3.8	0.0	0.0	0.0	0.0	2.1	1.0	0.6
	50%	10.	0.0	9.6	0.6	0.0	0.0	0.0	4.9	2.6	1.5
	75%	13.	0.0	14.	2.3	0.0	0.0	0.0	4.8	2.6	2.2
	100%	15.	0.0	6.8	1.7	0.0	0.0	0.0	6.0	3.7	1.9
Rated	0	8.9	0.0	7.2	0.0	0.0	0.0	0.0	4.8	2.2	1.7
	25%	6.8	0.0	4.2	0.0	0.0	0.0	0.0	2.2	1.2	0.6
	50%	4.8	0.0	4.0	0.0	0.0	0.0	0.0	5.8	3.3	2.1
	75%	5.2	0.0	9.9	2.6	0.0	0.0	0.0	5.7	3.3	2.0
	100%	6.3	0.0	12.	0.5	0.0	0.0	0.0	5.2	3.0	1.6

Condition		ppm Concentrations, D. D. 6V-71 Engine					ppm Concentrations, I. H. D407 Engine				
Speed	Load	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_6	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_6
Idle	0	3.9	0.0	1.4	2.8	0.0	4.2	0.0	5.0	1.0	0.6
Inter-	0	4.0	0.0	1.5	0.0	0.0	4.7	0.0	11.	1.8	2.0
mediate	25%	2.6	0.0	0.4	0.0	0.0	3.8	0.0	7.4	1.4	1.0
	50%	2.0	0.0	0.0	0.0	0.0	4.2	0.0	6.8	1.4	1.0
	75%	3.0	0.0	0.2	0.0	0.0	7.1	0.2	12.	2.0	3.2
	100%	2.7	0.0	3.7	0.5	0.0	43.	0.5	56.	12.	6.8
Rated	0	1.7	0.0	2.7	0.0	0.0	3.6	0.0	8.6	1.4	1.4
	25%	1.8	0.0	0.6	0.7	0.0	4.0	0.0	9.6	2.0	1.6
	50%	2.2	0.0	0.2	1.1	0.0	3.4	0.0	7.4	1.4	1.0
	75%	1.8	0.0	0.1	2.3	0.0	4.1	0.0	9.9	1.4	2.4
	100%	1.7	0.0	2.6	2.6	0.0	8.5	0.4	34.	3.0	12.

TABLE 6 (Cont'd). DATA ON LIGHT HYDROCARBON EMISSIONS FROM HEAVY-DUTY DIESEL ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

Condition		ppm Concentrations, J. D. 6404 Engine					ppm Concentrations, M-B. OM636 Engine				
Speed	Load	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_6	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_6
Idle	0	7.1	0.1	18.	3.0	0.5	3.1	0.0	3.8	0.0	0.0
Inter-mediate	0	18.	1.0	55.	8.0	12.	3.8	0.0	5.7	0.0	0.0
	25%	9.0	0.2	23.	5.1	2.7	3.4	0.0	7.4	0.0	0.0
	50%	7.1	0.1	14.	2.2	1.5	3.8	0.0	6.4	0.0	0.0
	75%	6.4	0.3	35.	1.7	6.9	2.9	0.0	5.2	0.0	0.0
	100%	16.	0.0	32.	7.3	1.4	3.4	0.0	8.9	0.0	0.0
Rated	0	8.2	0.0	21.	3.6	1.3	4.2	0.0	9.0	0.0	0.0
	25%	5.4	0.0	9.0	1.4	0.0	4.5	0.0	14.	0.0	0.0
	50%	2.8	0.0	15.	0.0	2.6	5.3	0.0	21.	0.0	0.0
	75%	3.8	0.3	41.	1.3	7.7	3.6	0.0	12.	0.0	0.0
	100%	5.1	0.3	35.	2.7	1.4	4.1	0.0	8.1	0.0	0.0

Condition		ppm Concentrations, Onan DJBA Engine					ppm Concentrations, Perkins 4.236 Engine				
Speed	Load	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_6	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_6
Idle	0	3.4	0.0	9.2	0.7	0.0	5.1	0.0	5.2	0.0	0.0
Inter-mediate	0	4.8	0.0	12.	1.6	0.0	9.0	0.0	6.8	0.0	0.0
	25%	2.7	7.9	0.0	0.0	0.0	4.5	0.0	5.1	0.0	0.0
	50%	3.2	0.0	8.8	0.7	0.0	2.3	0.0	2.9	0.0	0.0
	75%	4.6	0.0	8.0	1.6	0.0	2.8	0.0	5.4	0.0	0.0
	100%	22.	0.6	17.	8.6	2.7	28.	0.0	22.	5.3	0.0
Rated	0	6.0	0.0	16.	2.3	2.1	5.6	0.0	8.2	0.0	0.0
	25%	6.0	0.2	16.	5.9	1.7	7.8	0.0	6.6	0.0	0.0
	50%	4.6	0.1	7.6	9.6	1.4	1.7	0.0	4.6	0.0	0.0
	75%	1.9	0.0	6.2	0.6	0.0	3.0	0.0	5.4	0.0	0.0
	100%	4.1	0.0	8.2	1.3	0.0	13.	0.0	17.	3.2	0.0

TABLE 7. DATA ON LIGHT HYDROCARBON EMISSIONS FROM HEAVY-DUTY GASOLINE ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

Condition		ppm Concentrations, Ford G5000 Engine							ppm Concentrations, Hercules G-2300 Engine						
Speed	Load	CH_4	C_2H_6	C_2H_4	C_3H_8	C_2H_2	C_3H_6	C_4H_{10}	CH_4	C_2H_6	C_2H_4	C_3H_8	C_2H_2	C_3H_6	C_4H_{10}
Idle	0	512	28	162	0.0	186	56	0.0	924	26	259	0.0	741	70	0.0
Inter-	CT	1210	197	583	1.0	504	171	158.	555	67	271	3.6	364	93	66.
mediate	0	1850	46	365	0.0	861	106	0.0	370	27	243	0.0	189	58	0.0
	25%	595	28	181	0.0	177	69	0.0	315	22	175	0.0	119	109	0.0
	50%	465	21	135	0.0	134	55	0.0	192	10	86	0.0	61	32	0.0
	75%	378	18	107	0.0	94	43	0.0	239	12	104	0.0	82	44	0.0
	100%	476	23	95	0.0	75	49	0.0	323	7	97	1.8	85	59	0.0
Rated	CT	1320	203	741	2.0	582	189	122.	149	27	98	0.0	79	32	41.
	0	1010	42	279	0.0	393	77	0.0	366	17	170	0.0	190	38	0.0
	25%	535	30	183	0.0	161	65	0.0	284	16	138	0.0	99	44	0.0
	50%	386	21	135	0.0	111	50	0.0	219	12	105	0.0	67	41	0.0
	75%	376	18	117	0.0	92	42	0.0	303	13	126	0.0	83	52	0.0
	100%	300	17	101	0.0	71	43	0.0	226	10	98	0.0	69	41	0.0

Condition		ppm Concentrations, J. I. Case 159G Engine							ppm Concentrations, Wisconsin VH4D Engine						
Speed	Load	CH_4	C_2H_6	C_2H_4	C_3H_8	C_2H_2	C_3H_6	C_4H_{10}	CH_4	C_2H_6	C_2H_4	C_3H_8	C_2H_2	C_3H_6	C_4H_{10}
Idle	0	558	14	140	0.0	209	39	0.0	298	13	93	0.0	174	46	0.0
Inter-	CT	-	-	-	-	-	-	-	-	-	-	-	-	-	-
mediate	0	865	23	216	0.0	326	57	0.0	755	17	189	0.6	405	75	0.0
	25%	550	12	128	0.0	169	32	0.0	265	9	82	0.0	123	39	5.3
	50%	348	8	84	0.0	99	22	0.0	151	2	42	0.0	66	46	0.0
	75%	357	8	77	0.0	91	20	0.0	396	17	111	0.0	127	29	0.0
	100%	296	8	74	0.0	75	25	0.0	323	9	73	0.0	107	81	0.0
Rated	CT	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	0	305	12	97	0.0	84	45	0.0	408	22	138	0.0	185	52	0.0
	25%	476	14	122	0.0	152	46	0.0	478	22	173	0.0	201	103	0.0
	50%	286	12	91	0.0	86	35	0.0	314	13	90	0.0	90	81	0.0
	75%	369	13	103	0.0	106	41	0.0	262	12	88	0.0	94	57	0.0
	100%	488	16	137	0.0	168	52	0.0	272	24	112	0.0	79	41	0.0

investigation is outside the intended scope of this project. Likewise, it would serve no real purpose at this point to compute light hydrocarbon emissions on a mass or brake specific basis, so they appear only as concentrations.

The most comprehensive body of processed data to be presented in this subsection is the mode-by-mode summary of mass emissions (g/hr) and brake specific emissions (g/hp hr) for the twelve test engines. This summary makes up Tables 8 through 19, and includes aldehyde concentrations as well as the mass-based data. The data can be weighted on a mode-by-mode basis to compute composite mass and brake specific emissions, as was discussed in section III. C., and the first attempt at such a computation will utilize the weighting factors commonly used for on-highway engines (see section III. C.). The use of these factors gives a uniform basis for comparison of data generated under the subject program to a large body of existing data on other engines, but it does not carry with it the assertion that the on-highway factors necessarily apply to farm, construction, or industrial applications. The mode NO_x data have not been corrected for humidity, so if other composites are calculated, they will have to be corrected individually.

Subject to the foregoing qualifications, then, the composite brake specific emissions from the eight diesel engines tested are presented in Table 20, and those from the gasoline engines are shown in Table 21. The data on the diesels show considerable variation from engine to engine, depending on induction system, injection system, combustion chamber design, and so forth. Variation among the gasoline engines was much less pronounced than among the diesels, and had the J. I. Case been run with lower intake and exhaust restrictions the variation would probably have been smaller still. Note that operation of the Case engine (which was the first gasoline engine tested in the F, C, & I category) at high intake and exhaust restrictions was the result of the contractor's misinterpretation of information received regarding upcoming Federal test procedures for heavy-duty gasoline engines. The mistake was rectified prior to testing the other gasoline engines, but it rendered the Case data less usable than that for the other gasoline engines. The correct precedents for setting intake and exhaust restrictions were utilized on all the engines except the J. I. Case, namely the EMA-California ARB procedure(2) for diesels, and the new Federal regulations on gasoline engines(1).

Aldehydes were not measured for every mode, so the value for the average idle was given its normal weight (0. 2) and data for the other modes were given the weights 0. 8/n, where n was the number of modes during which data were taken. Later in the report, the brake specific data (with other weighting factors, if necessary) from test engines and those from outside sources will be used to estimate emission factors.

TABLE 8. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR AN ALLIS-CHALMERS 3500 DIESEL ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	42	27	20.9	130.	65.6	7.4	5.0	-	-	-	-	-
1500	0	44	29	31.7	170.	120.	12.	9.5	-	-	-	-	-
	12.5%	-	-	27.3	130.	290.	-	19.6	1.82	8.55	19.1	-	1.30
	25%	28	22	31.4	100.	460.	9.4	28.7	1.05	3.13	15.3	0.31	0.958
	37.5%	-	-	38.3	87.2	630.	-	38.5	0.860	2.15	13.9	-	0.858
	50%	33	32	41.6	110.	780.	12.	49.5	0.696	1.83	13.0	0.20	0.828
	62.5%	-	-	40.3	200.	1090.	-	60.5	0.539	2.64	12.5	-	0.808
	75%	20	16	39.0	300.	1115.	8.	72.0	0.437	3.49	12.4	0.09	0.801
	87.5%	-	-	26.5	920.	1260.	-	84.6	0.255	8.76	12.0	-	0.846
	100%	23	23	13.3	1880.	1260.	10.	98.0	0.113	15.81	10.6	0.09	0.817
1700	0	-	-	35.5	160.	150.	-	14.	-	-	-	-	-
	25%	-	-	34.4	99.2	460.	-	33.1	1.02	2.92	13.6	-	0.974
	50%	-	-	36.5	100.	790.	-	55.7	0.54	1.52	11.7	-	0.819
	75%	-	-	39.7	280.	1230.	-	79.6	0.39	2.72	12.1	-	0.796
	100%	-	-	15.8	1420.	1430.	-	107.	0.12	10.55	10.6	-	0.821
2000	0	-	-	30.0	140.	170.	-	18.	-	-	-	-	-
	25%	-	-	32.9	98.5	470.	-	39.1	0.89	2.67	12.7	-	1.06
	50%	-	-	33.4	110.	850.	-	63.3	0.45	1.53	11.5	-	0.855
	75%	-	-	36.9	190.	1330.	-	88.8	0.33	1.71	11.9	-	0.807
	100%	-	-	31.6	820.	1580.	-	117.	0.22	5.51	3.7	-	0.780
2200	0	20	18	40.0	130.	180.	9.3	22.4	-	-	-	-	-
	12.5%	-	-	37.9	130.	310.	-	31.9	2.03	5.82	16.6	-	1.71
	25%	18	16	42.8	110.	450.	9.1	43.5	1.08	2.78	11.4	0.24	1.17
	37.5%	-	-	42.3	110.	620.	-	55.7	0.755	1.97	11.2	-	0.994
	50%	18	16	42.1	103.	820.	10.	68.5	0.564	1.68	9.92	0.14	0.916
	62.5%	-	-	44.2	130.	1030.	-	80.6	0.474	1.46	11.0	-	0.867
	75%	25	23	46.7	160.	1280.	16.	93.8	0.418	1.47	11.4	0.15	0.853
	87.5%	-	-	47.5	250.	1510.	-	108.	0.363	1.92	11.5	-	0.834
	100%	27	25	45.8	430.	1680.	19.	120.	0.319	2.98	11.7	0.13	0.797

TABLE 9. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A CATERPILLAR D6-C DIESEL ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	26	12	7.31	57.2	20.9	5.6	6.2	-	-	-	-	-
1400	0	24	12	11.09	120.	52.2	11.	15.2	-	-	-	-	-
	12.5%	-	-	7.68	76.9	110.	-	23.4	0.479	4.57	6.61	-	1.46
	25%	14	4	6.56	40.4	190.	6.4	31.9	0.206	1.26	5.84	0.20	1.00
	37.5%	-	-	5.36	29.4	300.	-	40.9	0.111	0.61	6.11	-	0.849
	50%	13	5	5.17	23.8	390.	6.2	48.7	0.081	0.37	6.16	0.10	0.762
	62.5%	-	-	5.30	33.6	440.	-	60.7	0.659	0.42	5.46	-	0.756
	75%	13	7	5.15	36.3	440.	6.5	71.7	0.053	0.38	4.58	0.07	0.748
	87.5%	-	-	5.03	37.3	440.	-	84.0	0.044	0.33	3.89	-	0.764
	100%	9	5	4.43	51.0	450.	5.	97.0	0.034	0.39	3.46	0.04	0.746
1900	0	12	5	14.80	150.	82.4	7.1	25.3	-	-	-	-	-
	12.5%	-	-	7.70	196.1	130	-	33.5	0.412	5.17	7.02	-	1.90
	25%	7	6	6.99	73.7	210.	4.	44.5	0.185	1.97	5.49	0.1	1.19
	37.5%	-	-	6.71	63.4	300.	-	54.3	0.118	1.13	5.43	-	0.971
	50%	10	3	7.22	63.8	400.	5.8	64.5	0.109	0.85	5.42	0.08	0.865
	62.5%	-	-	6.67	50.9	490.	-	77.6	0.070	0.54	5.24	-	0.825
	75%	11	8	6.15	52.8	550.	7.2	89.8	0.054	0.47	4.92	0.06	0.816
	87.5%	-	-	5.84	60.6	590.	-	103.	0.044	0.46	4.52	-	0.786
	100%	10	5	6.48	73.2	620.	7.4	118.	0.043	0.49	4.18	0.05	0.789

TABLE 10. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A DETROIT DIESEL 6V-71 DIESEL ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	12	7	12.3	54.6	100.	3.0	5.6	-	-	-	-	-
1200	0	-	-	24.5	140.	170.	-	13.4	-	-	-	-	-
	25%	-	-	31.2	56.8	781.	-	36.7	0.969	1.76	24.3	-	1.14
	50%	-	-	33.7	30.0	1410.	-	59.5	0.513	0.457	21.4	-	0.904
	75%	-	-	39.7	100.	2070.	-	83.2	0.405	1.01	21.1	-	0.849
	100%	-	-	41.1	3810.	1650.	-	118.	0.317	29.30	12.7	-	0.906
1600	0	23	13	40.8	150.	310.	22.	22.4	-	-	-	-	-
	12.5%	-	-	39.7	92.5	660.	-	34.7	1.77	4.14	29.5	-	1.55
	25%	14	7	41.3	59.3	1040.	14.	47.1	0.964	1.38	24.4	0.34	1.10
	37.5%	-	-	46.0	47.3	1580.	-	59.7	0.715	1.07	24.5	-	0.927
	50%	13	8	46.5	40.6	1960.	14.	75.4	0.539	0.471	22.7	0.16	0.875
	62.5%	-	-	48.7	39.1	2510.	-	88.4	0.449	0.361	23.2	-	0.804
	75%	7	4	53.5	69.3	2970.	7.	104.	0.415	0.537	23.1	0.6	0.803
	87.5%	-	-	64.2	440.	3120.	-	124.	0.428	2.93	20.8	-	0.828
	100%	11	7	65.5	2350.	2770.	12.	143.	0.386	13.83	16.3	0.07	0.842
1800	0	-	-	62.9	130.	430.	-	27.5	-	-	-	-	-
	25%	-	-	59.9	55.0	1190.	-	53.7	1.31	1.20	25.9	-	1.17
	50%	-	-	55.8	38.6	2000.	-	83.2	0.603	0.416	21.6	-	0.898
	75%	-	-	58.6	84.8	3210.	-	120.	0.421	0.608	23.1	-	0.858
	100%	-	-	63.8	2170.	3250.	-	161.	0.342	11.7	17.5	-	0.847
2100	0	10	5	95.1	150.	730.	16.	36.5	-	-	-	-	-
	12.5%	-	-	87.7	110.	1120.	-	48.7	3.51	4.49	44.9	-	1.95
	25%	8	5	81.4	90.5	1620.	12.	63.9	1.58	1.76	31.4	0.2	1.28
	37.5	-	-	79.5	81.6	2070.	-	78.2	1.03	1.06	26.8	-	1.02
	50%	7	4	79.7	81.2	2680.	10.	96.6	0.768	0.783	25.9	0.1	0.966
	62.5%	-	-	76.9	72.3	3250.	-	110.	0.593	0.556	25.1	-	0.849
	75%	9	6	80.4	78.8	4030.	13.	135.	0.519	0.509	26.0	0.09	0.898
	87.5	-	-	83.7	180.	4330.	-	155.	0.440	0.960	23.7	-	0.862
	100%	10	7	86.7	760.	4180.	14.	175.	0.417	3.65	20.1	0.06	0.834

TABLE 11. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR AN INTERNATIONAL HARVESTER D407 DIESEL ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	22	16	34.67	34.05	33.87	3.1	2.8	-	-	-	-	-
1800	0	29	13	109.4	112.5	46.8	10	11.	-	-	-	-	-
	12.5%	-	-	93.0	111.3	86.0	-	18.	7.85	9.38	7.26	-	1.5
	25%	20	10	99.0	100.6	145.5	7.0	24.1	4.13	4.19	6.06	0.29	1.01
	37.5%	-	-	92.0	109.5	201.5	-	31.7	2.56	3.04	5.60	-	0.881
	50%	15	9	100.2	111.3	277.3	5.2	38.3	2.09	2.32	5.78	0.11	0.798
	62.5%	-	-	98.0	146.8	383.5	-	46.1	1.64	2.45	6.39	-	0.768
	75%	13	7	121.8	304.5	474.8	4.5	56.5	1.69	4.23	6.59	0.062	0.784
	87.5%	-	-	148.3	799.8	584.3	-	66.5	1.77	9.53	6.96	-	0.791
	100%	24	10	120.9	2340.5	624.5	8.3	77.2	1.26	24.4	6.49	0.086	0.803
2100	0	-	-	139.5	138.0	59.9	-	14.	-	-	-	-	-
	25%	-	-	118.5	135.5	172.0	-	28.5	4.46	5.10	6.47	-	1.07
	50%	-	-	120.5	154.0	343.0	-	46.1	2.30	2.94	6.54	-	0.878
	75%	-	-	141.0	288.5	619.5	-	63.9	1.80	3.68	7.90	-	0.815
	100%	-	-	153.5	2246.5	749.5	-	87.2	1.46	21.4	7.14	-	0.831
2300	0	-	-	148.5	149.0	81.9	-	17.	-	-	-	-	-
	25%	-	-	134.5	140.0	206.5	-	31.3	4.88	5.08	7.48	-	1.14
	50%	-	-	131.0	162.5	375.5	-	48.7	2.37	2.95	6.81	-	0.882
	75%	-	-	139.5	300.5	786.5	-	63.7	1.69	3.63	9.50	-	0.769
	100%	-	-	204.0	1903.5	963.5	-	91.8	1.86	17.31	8.76	-	0.835
2500	0	14	13	145.0	175.5	97.0	6.5	20.2	-	-	-	-	-
	12.5%	-	-	139.4	177.0	135.8	-	26.1	10.4	13.26	10.17	-	1.96
	25%	23	7	145.5	169.8	210.3	18.	34.3	5.26	6.12	7.59	0.65	1.24
	37.5%	-	-	139.8	164.3	291.0	-	41.5	3.40	4.00	7.10	-	1.01
	50%	32	17	149.8	162.8	415.8	15.	49.7	2.73	2.97	7.59	0.27	0.907
	62.5%	-	-	143.5	190.0	563.3	-	59.5	2.09	2.77	8.22	-	0.868
	75%	18	8	144.0	244.8	724.3	8.3	67.5	1.74	2.95	8.74	0.101	0.814
	87.5%	-	-	162.8	410.0	900.0	-	77.6	1.68	4.23	9.31	-	0.803
	100%	16	7	202.5	815.5	1008.8	7.5	88.0	1.85	7.44	9.21	0.068	0.804

TABLE 12. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A JOHN DEERE 6404 DIESEL ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	112	62	65.4	78.5	20.7	19.2	5.0	-	-	-	-	-
1500	0	209	141	280.	450.	23.6	64.2	15.	-	-	-	-	-
	12.5%	-	-	230.	280.	45.0	-	20.6	17.8	21.9	3.52	-	1.61
	25%	177	128	180.	140.	91.4	58.9	28.3	6.86	7.15	3.49	2.26	1.09
	37.5%	-	-	180.	140.	140.	-	35.9	4.46	3.48	3.54	-	0.919
	50%	137	95	190.	140.	190.	50.9	45.3	3.55	2.65	3.55	0.969	0.861
	62.5%	-	-	200.	170.	250.	-	53.1	3.09	2.53	3.89	-	0.813
	75%	138	97	210.	220.	290.	55.6	60.7	2.67	2.75	4.22	0.713	0.778
	87.5%	-	-	210.	490.	430.	-	72.6	2.25	5.33	4.67	-	0.797
	100%	111	66	180.	900.	500.	48.2	80.6	1.79	9.05	5.04	0.468	0.783
1700	0	-	-	180.	320.	14.9	-	17.	-	-	-	-	-
	25%	-	-	150.	210.	77.4	-	32.5	5.96	8.36	3.07	-	1.29
	50%	-	-	170.	150.	180.	-	50.5	3.30	2.84	3.44	-	0.986
	75%	-	-	210.	230.	350.	-	69.7	2.81	2.97	4.63	-	0.917
	100%	-	-	230.	580.	670.	-	91.2	2.27	5.75	6.58	-	0.894
1900	0	-	-	160.	240.	33.5	-	20.	-	-	-	-	-
	25%	-	-	140.	180.	100.	-	35.9	4.46	5.78	3.22	-	1.14
	50%	-	-	180.	130.	230.	-	57.5	2.87	2.11	3.61	-	0.905
	75%	-	-	230.	220.	450.	-	76.2	2.37	2.32	4.72	-	0.803
	100%	-	-	270.	440.	900.	-	98.4	2.15	3.49	7.10	-	0.781
2200	0	139	60	190.	250.	57.3	63.5	24.3	-	-	-	-	-
	12.5%	-	-	170.	200.	120.	-	36.7	8.74	10.2	6.41	-	1.82
	25%	86	51	150.	170.	160.	44.	44.9	4.50	4.90	4.63	1.27	1.31
	37.5%	-	-	240.	110.	250.	-	55.9	4.73	2.10	4.87	-	1.08
	50%	74	49	200.	100.	330.	43.	67.1	2.81	1.44	4.83	0.62	0.973
	62.5%	-	-	230.	110.	470.	-	79.4	2.60	1.25	5.46	-	0.916
	75%	142	83	240.	160.	630.	91.7	89.6	2.34	1.53	6.12	0.917	0.896
	87.5%	-	-	260.	260.	880.	-	102.	2.15	2.13	7.28	-	0.848
	100%	102	68	280.	350.	1190.	72.5	112.	2.06	2.55	7.29	0.517	0.802

TABLE 13. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A MERCEDES-BENZ OM636 DIESEL ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	24	18	3.59	14.4	12.8	1.1	2.4	-	-	-	-	-
1400	0	27	21	6.50	27.8	11.5	2.2	4.2	-	-	-	-	-
	12.5%	-	-	6.59	18.4	20.7	-	6.2	3.22	8.99	10.1	-	2.9
	25%	24	19	6.50	18.6	26.6	2.0	7.2	1.59	4.56	6.50	0.48	1.8
	37.5%	-	-	6.73	18.0	32.3	-	8.4	1.09	2.91	5.22	-	1.4
	50%	23	21	6.88	18.3	38.1	1.8	10.	0.84	2.24	4.66	0.22	1.2
	62.5%	-	-	6.60	18.7	38.9	-	11.	0.64	1.83	3.78	-	1.1
	75%	26	24	5.85	19.4	37.5	2.0	13.	0.47	1.60	3.86	0.17	1.0
	87.5%	-	-	5.92	24.0	35.9	-	15.	0.41	1.68	2.50	-	1.1
	100%	26	25	8.68	87.7	42.4	2.1	17.	0.53	5.37	2.60	0.13	1.0
1700	0	-	-	8.44	32.4	15.7	-	5.8	-	-	-	-	-
	25%	-	-	9.81	31.4	28.0	-	9.2	1.89	6.04	5.39	-	1.8
	50%	-	-	11.7	32.8	42.2	-	12.	1.12	3.15	4.05	-	1.2
	75%	-	-	7.43	23.6	51.2	-	16.	0.48	1.51	3.28	-	1.0
	100%	-	-	7.71	13.0	44.3	-	20.8	0.37	6.21	2.13	-	0.998
2100	0	-	-	8.48	23.0	13.5	-	6.0	-	-	-	-	-
	25%	-	-	26.7	42.5	30.3	-	11.	4.05	6.44	4.59	-	1.7
	50%	-	-	10.4	37.6	43.7	-	16.	0.79	2.87	3.34	-	1.2
	75%	-	-	7.43	33.0	58.9	-	21.4	0.38	1.68	3.00	-	1.08
	100%	-	-	9.74	200.	59.9	-	28.3	0.37	7.64	2.29	-	1.08
2400	0	34	27	20.7	69.9	19.0	5.3	8.4	-	-	-	-	-
	12.5%	-	-	26.5	44.0	23.3	-	11.	7.68	13.0	6.80	-	3.2
	25%	35	26	28.4	39.1	31.7	4.7	13.	3.94	5.44	4.40	0.65	1.8
	37.5%	-	-	23.6	41.6	40.7	-	15.	2.39	4.23	4.09	-	1.5
	50%	29	22	20.7	51.3	54.6	3.9	18.	1.44	3.58	3.80	0.27	1.2
	62.5%	-	-	17.1	36.9	64.7	-	20.6	0.97	2.91	3.63	-	1.15
	75%	28	22	12.6	49.1	70.6	3.7	23.2	0.58	2.28	3.27	0.17	1.07
	87.5%	-	-	10.9	98.8	67.6	-	26.7	0.44	3.93	2.70	-	1.07
	100%	22	19	7.7	250.	63.4	2.9	30.3	0.27	8.81	2.21	0.10	1.06

TABLE 14. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR AN ONAN DJBA DIESEL ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	20	12	6.87	31.1	11.1	0.79	2.1	-	-	-	-	-
1500	0	-	-	6.92	33.1	11.5	-	2.5	-	-	-	-	-
	25%	-	-	6.99	12.9	29.3	-	3.8	3.88	6.31	14.1	-	1.8
	50%	-	-	4.99	12.3	43.3	-	5.1	1.20	2.95	10.3	-	1.2
	75%	-	-	5.95	20.6	56.1	-	8.2	0.97	3.33	9.12	-	1.3
	100%	-	-	8.75	49.3	30.3	-	8.7	1.03	5.74	3.67	-	1.0
1800	0	12	6	9.90	58.2	11.5	0.62	3.0	-	-	-	-	-
	12.5%	-	-	9.34	28.7	23.6	-	4.1	6.93	21.3	17.5	-	3.0
	25%	12	7	9.47	18.8	36.1	0.65	4.8	3.50	7.01	13.4	0.24	1.8
	37.5%	-	-	7.89	15.7	46.5	-	5.5	1.96	3.90	11.6	-	1.4
	50%	17	7	7.38	13.9	49.9	0.89	6.4	1.38	2.61	9.30	0.17	1.2
	62.5%	-	-	6.84	13.4	50.6	-	7.2	1.02	1.99	7.54	-	1.1
	75%	36	32	7.32	14.9	46.9	1.9	8.3	0.91	1.86	5.82	0.24	1.0
	87.5%	-	-	7.81	19.8	40.4	-	9.5	0.83	2.11	4.30	-	1.0
	100%	7	6	9.68	50.7	32.9	0.37	11.	0.91	4.79	3.10	0.035	1.1
2100	0	-	-	20.9	66.7	14.3	-	3.8	-	-	-	-	-
	25%	-	-	11.7	32.2	30.1	-	5.5	4.00	11.5	10.8	-	1.9
	50%	-	-	7.11	19.6	48.1	-	7.0	1.25	3.51	8.55	-	1.2
	75%	-	-	5.52	14.8	47.7	-	9.0	0.66	1.80	5.79	-	1.1
	100%	-	-	9.33	41.2	38.7	-	13.	0.77	3.35	3.26	-	1.1
2400	0	33	16	20.2	70.3	15.1	2.3	4.4	-	-	-	-	-
	12.5%	-	-	16.6	40.5	22.9	-	5.3	10.2	24.9	14.1	-	3.3
	25%	19	11	12.9	33.6	33.7	1.3	6.6	3.94	10.2	10.3	0.41	2.0
	37.5%	-	-	9.64	26.4	50.9	-	7.5	1.96	5.38	10.3	-	1.5
	50%	13	6	10.2	23.3	46.1	0.91	8.7	1.55	3.55	7.03	0.14	1.3
	62.5%	-	-	7.43	18.5	50.9	-	9.6	0.91	2.26	6.24	-	1.2
	75%	9	7	7.25	17.8	48.8	0.62	11.	0.74	1.81	4.96	0.063	1.1
	87.5%	-	-	7.18	15.2	43.3	-	12.	0.62	1.32	3.77	-	1.0
	100%	12	9	11.1	31.8	43.6	0.87	15.	0.88	2.51	3.50	0.069	1.2

TABLE 15. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A PERKINS 4.236 DIESEL ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	31	16	8.47	14.4	8.65	1.8	1.5	-	-	-	-	-
1450	0	39	24	23.1	46.4	25.9	7.3	5.6	-	-	-	-	-
	12.5%	-	-	19.7	52.4	54.1	-	8.8	2.91	7.75	8.01	-	1.3
	25%	25	13	18.3	53.9	99.5	4.4	12.	1.40	4.14	7.63	0.34	0.91
	37.5%	-	-	17.3	42.4	170.	-	15.	0.89	2.19	8.74	-	0.79
	50%	43	35	17.9	30.8	260.	7.9	20.2	0.68	1.17	9.89	0.30	0.766
	62.5%	-	-	14.2	26.6	350.	-	24.5	0.50	0.81	10.7	-	0.748
	75%	23	12	12.5	36.2	450.	4.1	28.9	0.32	0.93	11.4	0.10	0.740
	87.5%	-	-	14.9	145.	500.	-	33.7	0.33	3.15	10.9	-	0.738
	100%	30	22	11.0	820.	480.	5.5	40.7	0.25	16.2	9.43	0.11	0.803
1700	0	-	-	29.7	55.2	33.4	-	4.6	-	-	-	-	-
	25%	-	-	26.7	59.9	120.	-	13.6	1.69	4.19	8.30	-	0.95
	50%	-	-	25.1	36.5	310.	-	22.4	0.87	1.27	10.6	-	0.776
	75%	-	-	25.2	29.2	530.	-	31.3	0.59	0.68	12.5	-	0.734
	100%	-	-	17.6	970.	540.	-	45.9	0.30	16.6	9.32	-	0.786
2100	0	-	-	32.5	54.7	51.0	-	8.8	-	-	-	-	-
	25%	-	-	28.6	64.9	140.	-	17.	0.20	3.81	8.50	-	0.99
	50%	-	-	25.0	53.0	330.	-	25.5	0.43	1.58	9.86	-	0.760
	75%	-	-	21.8	34.4	670.	-	37.5	0.74	0.67	13.0	-	0.970
	100%	-	-	13.5	820.	740.	-	55.3	1.68	11.9	10.8	-	0.804
2400	0	34	21	35.7	73.2	38.8	8.2	10.	-	-	-	-	-
	12.5%	-	-	30.9	87.3	72.1	-	15.	3.14	9.00	7.43	-	1.6
	25%	53	34	24.5	96.0	120.	14.	20.4	1.27	5.00	6.24	0.80	1.06
	37.5%	-	-	19.8	89.6	190.	-	25.7	0.69	3.14	6.68	-	0.903
	50%	51	34	18.8	69.4	310.	14.	30.9	0.50	1.81	7.99	0.37	0.806
	62.5%	-	-	14.5	58.3	450.	-	36.7	0.26	1.22	9.51	-	0.770
	75%	19	10	12.3	56.2	700.	5.4	43.7	0.21	1.16	14.7	0.09	0.760
	87.5%	-	-	16.0	170.	790.	-	50.3	0.24	2.57	11.9	-	0.754
	100%	37	26	6.69	770.	770.	10.5	60.7	0.17	10.2	10.2	0.14	0.803

TABLE 16. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A FORD G5000 GASOLINE ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	84	57	87.2	549.	2.43	2.03	1.2	-	-	-	-	-
1400	CT	192	126	434.	625.	0.443	5.3	1.3	-	-	-	-	-
	0	71	46	260.	2770.	3.75	3.2	2.7	-	-	-	-	-
	12.5%	-	-	130.	3110.	17.4	-	3.5	19.8	470.	2.61	-	0.53
	25%	71	49	150.	3610.	41.3	5.4	4.41	11.0	270.	3.04	0.40	0.324
	37.5%	-	-	180.	4320.	73.0	-	5.54	8.80	220.	3.98	-	0.277
	50%	70	49	190.	4740.	110.	8.0	6.51	7.00	180.	4.26	0.30	0.244
	62.5%	-	-	180.	3940.	150.	-	7.37	5.38	150.	4.61	-	0.223
	75%	77	56	200.	4770.	230.	12.	8.43	5.05	120.	5.79	0.30	0.212
	87.5%	-	-	200.	4810.	320.	-	9.48	4.21	100.	6.90	-	0.203
	100%	82	64	230.	5640.	330.	15.	9.99	4.21	110.	6.05	0.28	0.186
1600	0	-	-	265.	2100.	4.24	-	2.9	-	-	-	-	
	25%	-	-	161.	3970.	38.2	-	4.91	11.1	272.	2.62	-	0.337
	50%	-	-	205.	5160.	116.	-	6.90	6.54	166.	3.75	-	0.223
	75%	-	-	208.	5280.	238.	-	8.93	4.60	116.	5.28	-	0.198
	100%	-	-	236.	6040.	310.	-	11.2	3.95	101.	5.20	-	0.188
1900	0	-	-	182.	2360.	4.34	-	2.7	-	-	-	-	-
	25%	-	-	160.	4380.	42.6	-	4.99	9.50	260.	2.52	-	0.297
	50%	-	-	302.	5380.	141.	-	7.45	8.82	158.	4.12	-	0.218
	75%	-	-	236.	6380.	264.	-	10.4	4.53	123.	5.07	-	0.200
	100%	-	-	275.	6940.	384.	-	13.3	4.09	104.	5.72	-	0.199
2100	CT	194	129	538.	667.	0.406	6.73	1.3	-	-	-	-	-
	0	84	58	180.	3040.	10.7	5.3	3.6	-	-	-	-	-
	12.5%	-	-	170.	3740.	48.5	-	4.8	18.9	430.	5.52	-	0.545
	25%	70	49	180.	4790.	110.	7.3	6.05	10.0	280.	6.06	0.42	0.347
	37.5%	-	-	190.	5220.	170.	-	7.29	7.43	200.	6.64	-	0.281
	50%	76	57	210.	5610.	210.	11.	8.54	5.91	160.	7.37	0.32	0.243
	62.5%	-	-	230.	5810.	340.	-	9.67	5.20	110.	7.76	-	0.221
	75%	63	46	220.	5950.	410.	13.	11.5	4.23	110.	7.77	0.25	0.220
	87.5%	-	-	220.	5900.	460.	-	12.2	3.57	100.	7.48	-	0.198
	100%	63	48	250.	5150.	720.	16.	13.7	3.51	70.	10.1	0.22	0.193

TABLE 17. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A HERCULES G-2300 GASOLINE ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	41	28	65.6	1200.	0.993	0.85	1.2	-	-	-	-	-
1450	CT	149	96	620.	740.	0.403	3.84	1.3	-	-	-	-	-
	0	18	9	71.3	1310.	4.46	0.75	2.4	-	-	-	-	-
	12.5%	-	-	110.	2410.	14.3	-	3.6	16.9	360.	2.14	-	0.54
	25%	21	12	150.	4950.	33.6	1.7	4.92	11.1	230.	2.43	0.13	0.356
	37.5%	-	-	190.	5540.	57.0	-	6.48	9.26	240.	2.78	-	0.316
	50%	29	22	200.	5890.	81.8	3.6	7.29	7.49	200.	3.01	0.13	0.269
	62.5%	-	-	220.	6460.	100.	-	8.11	6.61	170.	3.04	-	0.240
	75%	37	29	230.	7610.	130.	5.7	9.21	5.59	160.	3.29	0.14	0.228
	87.5%	-	-	260.	12800.	210.	-	10.6	5.42	160.	4.46	-	0.225
	100%	21	15	310.	1249.	120.	4.3	13.0	5.74	240.	2.26	0.08	0.242
1750	0	-	-	85.3	1680.	8.32	-	3.0	-	-	-	-	-
	25%	-	-	170.	4790.	40.9	-	5.54	10.7	300.	2.59	-	0.351
	50%	-	-	220.	6770.	120.	-	8.15	6.93	210.	3.87	-	0.257
	75%	-	-	240.	8260.	200.	-	10.7	5.06	170.	4.12	-	0.226
	100%	-	-	260.	13180.	200.	-	13.8	4.17	210.	3.15	-	0.220
2100	0	-	-	95.3	2500.	6.93	-	3.3	-	-	-	-	-
	25%	-	-	164.	5490.	49.9	-	6.28	8.94	300.	2.54	-	0.347
	50%	-	-	230.	7640.	150.	-	9.32	6.35	200.	4.29	-	0.261
	75%	-	-	270.	9820.	240.	-	12.0	4.99	180.	4.52	-	0.224
	100%	-	-	290.	12620.	250.	-	14.6	4.00	180.	3.53	-	0.205
2400	CT	141	81	640.	280.	0.359	4.43	1.0	-	-	-	-	-
	0	31	19	100.	3140.	8.90	2.1	3.9	-	-	-	-	-
	12.5%	-	-	150.	4680.	22.5	-	5.54	14.9	480.	2.30	-	0.565
	25%	35	21	180.	5760.	42.9	4.1	6.98	9.17	300.	2.56	0.22	0.364
	37.5%	-	-	200.	6650.	83.1	-	8.54	7.21	240.	3.45	-	0.304
	50%	45	30	220.	7460.	120.	7.4	9.71	6.04	200.	3.37	0.20	0.258
	62.5%	-	-	250.	8480.	140.	-	11.2	5.40	180.	3.35	-	0.238
	75%	33	21	270.	9090.	220.	7.2	12.6	4.88	170.	4.19		0.224
	87.5%	-	-	290.	10130.	360.	-	14.4	4.45	150.	5.43	-	0.218
	100%	45	28	290.	9130.	440.	12.	15.4	3.89	120	5.81	0.17	0.204

TABLE 18. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A J. I. CASE 159G GASOLINE ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	112	61	54.4	1090.	1.26	2.09	1.0	-	-	-	-	-
1400	CT	-	-	547.	732.	0.42	-	1.2	-	-	-	-	-
	0	111	72	130.	2780.	2.60	3.98	2.2	-	-	-	-	-
	12.5%	-	-	120.	3260.	4.66	-	2.7	30.1	800.	1.14	-	0.65
	25%	154	90	28.8	3920.	9.24	8.24	3.4	14.9	480.	1.14	1.02	0.42
	37.5%	-	-	140.	4410.	14.3	-	3.94	11.1	300.	1.18	-	0.323
	50%	114	64	150.	4930.	19.7	9.05	4.95	9.26	300.	1.23	0.558	0.306
	62.5%	-	-	150.	5220.	41.4	-	5.23	6.14	260.	2.02	-	0.256
	75%	114	66	160.	5630.	48.4	10.4	5.81	6.63	230.	1.97	0.423	0.236
	87.5%	-	-	170.	5970.	95.7	-	6.55	6.35	220.	3.48	-	0.231
	100%	139	80	180.	6530.	79.5	17.1	6.98	5.73	200.	2.47	0.532	0.218
1600	0	-	-	136.	2700.	2.17	-	2.2	-	-	-	-	-
	25%	-	-	154.	4600.	9.61	-	3.8	18.3	548.	1.14	-	0.46
	50%	-	-	174.	5960.	20.6	-	5.34	10.1	347.	1.19	-	0.311
	75%	-	-	195.	6740.	48.0	-	6.51	7.22	250.	1.78	-	0.241
	100%	-	-	196.	6700.	170.	-	8.74	5.83	200.	5.07	-	0.260
1900	0	-	-	132.	3390.	3.68	-	2.7	-	-	-	-	-
	25%	-	-	145.	5570.	11.8	-	4.68	13.9	535.	1.13	-	0.450
	50%	-	-	170.	6500.	48.6	-	6.20	7.75	295.	2.21	-	0.282
	75%	-	-	253.	7300.	75.0	-	7.49	8.01	231.	2.38	-	0.237
	100%	-	-	200.	6770.	198.	-	9.09	5.06	171.	5.01	-	0.230
2100	CT	-	-	908.	477.	0.32	-	1.2	-	-	-	-	-
	0	104	64	210.	3920.	8.49	6.3	3.7	-	-	-	-	-
	12.5%	-	-	110.	4790.	9.59	-	4.14	20.5	930.	1.88	-	0.80
	25%	106	79	120.	5140.	16.0	7.84	4.64	11.7	490.	1.63	0.739	0.438
	37.5%	-	-	140.	5430.	37.6	-	5.27	8.90	350.	2.40	-	0.340
	50%	114	58	160.	6080.	53.4	11.4	6.09	7.23	280.	2.46	0.545	0.293
	62.5%	-	-	200.	6870.	54.5	-	6.83	8.01	270.	2.12	-	0.265
	75%	107	66	130.	7480.	65.1	13.3	7.57	5.52	240.	2.11	0.431	0.245
	87.5%	-	-	180.	8040.	100.	-	8.54	5.06	220.	2.76	-	0.235
	100%	124	71	190.	8100.	145.	19.0	9.21	4.65	200.	3.51	0.461	0.223

TABLE 19. MASS EMISSIONS AND BRAKE SPECIFIC EMISSIONS OF MAJOR GASEOUS POLLUTANTS AND ALDEHYDE CONCENTRATIONS FOR A WISCONSIN VH4D GASOLINE ENGINE

Condition		Concentrations, ppm		Mass Emissions, g/hr					Specific Emissions, g/bhp hr				
Speed	Load	RCHO	HCHO	HC	CO	NO_x	RCHO	SO_x	HC	CO	NO_x	RCHO	SO_x
Idle	0	32	18	64.2	1069.	1.04	0.5	1.0	-	-	-	-	-
1700	0	28	13	110.	2044.	2.03	0.8	1.8	-	-	-	-	-
	12.5%	-	-	82.6	2277.	3.67	-	2.1	31.7	805.	1.29	-	0.75
	25%	23	9	84.4	2166.	11.9	1.0	2.7	14.9	380.	2.09	5.5	0.48
	37.5%	-	-	110.	2823.	22.1	-	3.1	12.5	332.	2.60	-	0.37
	50%	25	12	110.	3362.	29.5	1.5	3.6	10.1	297.	2.60	7.6	0.32
	62.5%	-	-	120.	3685.	43.5	-	4.1	8.79	260.	3.07	-	0.29
	75%	30	16	120.	3735.	67.0	2.0	4.41	6.82	336.	3.94	0.12	0.259
	87.5%	-	-	110.	3999.	160.	-	5.19	5.73	202.	8.15	-	0.262
	100%	23	13	120.	4865.	110.	2.2	5.81	5.37	215.	4.96	0.10	0.256
2000	0	-	-	89.8	2083.	3.19	-	2.0	-	-	-	-	-
	25%	-	-	91.8	2573.	17.9	-	2.9	14.1	396.	2.76	-	0.44
	50%	-	-	120.	3829.	47.9	-	4.29	9.24	295.	3.68	-	0.330
	75%	-	-	110.	4522.	120.	-	5.31	5.72	232.	6.30	-	0.272
	100%	-	-	120.	4784.	180.	-	6.44	4.42	184.	6.94	-	0.248
2400	0	-	-	78.4	1969.	4.43	-	2.2	-	-	-	-	-
	25%	-	-	110.	3495.	19.4	-	3.5	14.3	472.	2.62	-	0.47
	50%	-	-	130.	4285.	67.9	-	4.88	8.68	290.	4.60	-	0.329
	75%	-	-	120.	5088.	170.	-	6.20	5.60	230.	7.74	-	0.279
	100%	-	-	140.	5241.	230.	-	7.29	4.70	177.	7.83	-	0.246
2800	0	23	12	120.	2636.	6.83	1.1	2.8	-	-	-	-	-
	12.5%	-	-	120.	3278.	11.4	-	3.4	30.4	821.	2.85	-	0.85
	25%	27	14	150.	4050.	22.0	2.5	4.14	18.3	507.	2.75	0.31	0.52
	37.5%	-	-	150.	4554.	35.2	-	4.72	14.5	440.	3.39	-	0.450
	50%	23	12	150.	5041.	71.1	2.1	5.46	9.74	320.	4.51	0.50	0.346
	62.5%	-	-	150.	5544.	130.	-	6.40	7.42	281.	6.55	-	0.323
	75%	21	12	150.	5625.	180.	2.5	6.87	6.21	237.	7.64	0.10	0.290
	87.5%	-	-	150.	5050.	300.	-	7.26	5.48	182.	10.9	-	0.262
	100%	26	14	190.	5497.	270.	3.7	8.00	6.04	174.	8.64	0.37	0.253

TABLE 20. CYCLE COMPOSITE BRAKE SPECIFIC GASEOUS EMISSIONS FROM EIGHT FARM, CONSTRUCTION, AND INDUSTRIAL DIESEL ENGINES (ON-HIGHWAY WEIGHTING FACTORS)

		Composite Brake Specific Emissions, g/bhp hr					
Engine	Run	HC	CO	NO_x	$HC+NO_x$	*RCHO	*SO_x
Allis-Chalmers 3500	1	0.577	4.91	11.9	12.5	----	-----
	2	0.629	4.77	11.9	12.5	----	-----
	3	0.590	4.46	10.6	11.2	----	-----
	4	0.668	4.82	12.1	12.8	----	-----
	5	0.631	4.38	11.5	12.2	----	-----
	6	0.595	4.94	11.2	11.8	----	-----
	Avg.	0.615	4.71	11.5	12.2	0.20	0.920
Caterpillar D6C	1	0.046	1.00	5.12	5.16	----	-----
	5	0.175	1.22	5.18	5.35	----	-----
	6	0.154	1.17	5.28	5.43	----	-----
	Avg.	0.125	1.13	5.19	5.31	0.12	0.891
Detroit Diesel 6V-71	3	0.776	2.57	20.4	21.2	----	-----
	4	0.745	3.09	19.6	20.4	----	-----
	5	0.586	3.22	20.5	21.1	----	-----
	Avg.	0.702	2.96	20.2	20.9	0.15	0.958
International Harvester D407	4	2.74	7.80	8.12	10.9	----	-----
	5	2.93	7.52	8.30	11.2	----	-----
	6	2.63	6.92	8.19	10.8	----	-----
	7	2.51	7.20	8.13	10.6	----	-----
	Avg.	2.70	7.36	8.18	10.9	0.19	0.914
John Deere 6404	1	3.94	4.63	5.45	9.39	----	-----
	2	3.65	3.82	5.97	9.62	----	-----
	3	3.64	4.75	5.60	9.24	----	-----
	5	3.72	4.99	6.07	9.79	----	-----
	Avg	3.74	4.54	5.77	9.51	1.1	0.960
Mercedes-Benz OM636	1	1.02	5.36	3.64	4.66	----	-----
	2	1.22	5.30	3.29	4.51	----	-----
	3	1.52	5.94	3.52	5.04	----	-----
	4	1.34	5.80	3.43	4.78	----	-----
	5	1.24	4.28	2.96	4.20	----	-----
	6	1.12	4.18	3.19	4.32	----	-----
	7	1.03	4.58	3.23	4.27	----	-----
	Avg	1.21	5.06	3.33	4.54	0.30	1.33
Onan DJBA	2	1.72	6.51	6.72	8.44	----	-----
	3	2.12	6.01	6.61	8.73	----	-----
	4	1.84	6.21	6.60	8.44	----	-----
	Avg.	1.89	6.24	6.64	8.54	0.21	1.40
Perkins 4.236	1	0.576	4.98	10.7	11.3	----	-----
	2	0.585	5.12	10.4	11.0	----	-----
	3	0.645	4.94	10.6	11.3	----	-----
	4	0.651	4.71	11.1	11.7	----	-----
	5	0.739	5.29	10.5	11.2	----	-----
	6	0.757	4.71	11.1	11.9	----	-----
	Avg.	0.659	4.96	10.7	11.4	0.27	0.848

*Computed from average emissions and power, not from individual run values

TABLE 21. CYCLE COMPOSITE BRAKE SPECIFIC GASEOUS EMISSIONS FROM FOUR FARM, CONSTRUCTION, AND INDUSTRIAL GASOLINE ENGINES (ON-HIGHWAY WEIGHTING FACTORS)

		Composite Brake Specific Emissions, g/bhp hr					
Engine	Run	HC	CO	NO_x	$HC+NO_x$	*RCHO	*SO_x
Ford G5000	1	8.92	171	6.36	15.3	----	-----
	2	8.80	159	6.94	15.7	----	-----
	3	8.91	155	6.78	15.7	----	-----
	4	8.89	157	6.73	15.6	----	-----
	5	8.78	153	6.68	15.5	----	-----
	Avg.	8.86	159	6.70	15.6	0.34	0.259
Hercules G-2300	2	8.16	210	4.05	12.2	----	-----
	3	8.82	201	4.07	12.9	----	-----
	4	9.08	222	4.32	13.4	----	-----
	5	9.86	209	3.89	13.8	----	-----
	Avg.	8.98	210	4.08	13.1	0.17	0.278
†J.I. Case 159G	3	11.5	305	2.35	13.8	----	-----
	4	12.8	302	2.55	15.4	----	-----
	5	14.6	333	1.73	16.3	----	-----
	6	14.5	326	2.15	16.6	----	-----
	Avg.	13.4	316	2.20	15.5	**0.67	0.316
Wisconsin VH4D	1	15.6	300	5.10	20.7	----	-----
	2	8.11	321	5.50	13.6	----	-----
	3	9.58	301	5.28	14.9	----	-----
	4	9.66	315	5.21	14.9	----	-----
	Avg.**	10.7	309	5.27	16.0	0.15	0.355

*computed from average emissions and power, not from individual run values
†high intake and exhaust restrictions used on this engine during tests
**does not include CT modes at intermediate and rated speeds

These estimates will be made separately for the farm, construction, and industrial applications, taking into account the different duty cycles encountered in each application.

B. Results of Particulate Emissions Tests

Particulate emissions from the F, C, & I engines were measured by the experimental dilution-type sampling device already described in section III. Since sampling was as near isokinetic as possible, and since no corrections for retention of particles in the sampling system upstream of the filter were made, it is felt that the normal experimental error was in the direction of low concentrations. Thus, it seems logical that the particulate results should tend to be conservative rather than high, which is preferable to error in the other direction when making impact assessments based on small samples.

The particulate results represent 308 tests (208 on the diesels and 100 on the gasoline engines), and all the individual run data will be presented to document the repeatability of the procedure. This full presentation of data should permit independent assessment of the data on each engine, and it will be obvious that repeatability differed considerably from engine to engine. The amounts of variation due to engine and to procedure have not been determined. Sampling was limited to seven conditions on each engine (0, half, and full loads at intermediate and rated speeds, plus low idle) to prevent using an inordinate amount of analysis time.

The individual mode and average mode particulate concentration data on each engine are given in Table 22, and if the specific crankshaft speeds used are of interest, they can be obtained from Table 3. Particulate levels for the diesels correlated to some extent with visible smoke, especially at high smoke levels, but sometimes a considerable amount of particulate was measured under conditions where smoke was barely readable. Invariably, however, high visible smoke was measured as a high particulate level.

Making the assumption that exhaust molecular weight was equal to that of air, mass and brake specific particulate rates were calculated for each of the engines, and these data appear in Table 23. For these computations, average idle modes were weighted 0.2, and the other six modes were weighted 0.8/6 = 0.133. These weighting factors yield a load factor for the composite cycle of 0.4, just like those used for gaseous emissions data. The weighting factors can be revised to reflect other operating cycles, if necessary.

C. Results of Diesel Smoke Tests

Smoke tests consisting of accelerations and lug-downs as required by Federal Regulations(1) were performed on seven of the eight diesel engines tested. The exception was the Onan DJBA engine, which was operated on a small dynamometer having no extended inertia capability. The Federal smoke evaluation data are given in full in Appendix B, and the results are summarized in Table 24. Several of the engines which should have been operated with 3 inch exhaust pipe for the smoke tests had already been fitted with 4 inch pipe for gaseous emissions tests, so it was left in place for the smoke tests and the results were "corrected" by Bouguer's Law(13, 14). The "c factor" is the average of the nine highest 1/2-second opacity readings during both the accelerations and the lug-downs, and its computation will

TABLE 22. PARTICULATE CONCENTRATION DATA ON F, C, & I ENGINES

Condition		Particulate Results, mg/SCF					Particulate Results, mg/SCF				
Speed	Load	Run 1	Run 2	Run 3	Run 4	Avg.	Run 1	Run 2	Run 3	Run 4	Avg.
		Allis-Chalmers 3500					Caterpillar D6C				
Idle	0	6.07	4.65	4.70	5.28	5.18	2.31	2.38	2.43	--	2.37
Inter.	0	3.82	3.24	3.75	3.60	3.60	0.90	1.22	0.60	--	0.94
Inter.	half	3.65	4.94	3.54	3.81	3.98	1.11	1.09	1.41	--	1.20
Inter.	full	16.5	18.9	16.2	17.8	17.4	1.59	1.62	--	--	1.60
Rated	0	2.54	3.16	2.45	2.35	2.62	1.44	0.44	0.62	--	0.83
Rated	half	3.46	3.26	3.44	3.39	3.39	1.96	2.73	2.09	1.36	2.04
Rated	full	3.50	3.84	3.43	3.69	3.62	2.35	2.45	--	--	2.40
		Detroit Diesel 6V-71					International D407				
Idle	0	0.57	0.79	0.54	1.59	0.87	2.50	4.81	3.90	6.94	4.54
Inter.	0	0.17	0.43	0.38	0.30	0.32	4.01	2.39	5.04	5.87	4.33
Inter.	half	0.53	0.38	0.78	0.56	0.56	6.53	10.2	7.28	8.52	8.13
Inter.	full	0.68	0.53	0.59	0.63	0.61	19.5	21.8	19.3	18.4	19.8
Rated	0	0.22	0.24	0.10	0.32	0.22	5.65	7.13	5.62	6.05	6.11
Rated	half	0.84	0.64	0.61	0.43	0.63	6.40	7.28	5.47	9.42	7.14
Rated	full	0.56	0.82	0.77	--	0.72	10.5	11.8	11.6	14.3	12.0
		John Deere 6404					Mercedes-Benz OM636				
Idle	0	4.00	4.44	4.40	4.67	4.50	2.48	4.52	2.37	--	3.12
Inter.	0	6.90	8.40	6.39	7.27	7.24	3.54	3.31	3.32	--	3.39
Inter.	half	6.04	7.42	7.09	8.23	7.20	5.26	5.80	5.60	--	5.55
Inter.	full	21.5	22.0	22.3	23.6	22.4	10.4	8.27	9.74	9.19	9.40
Rated	0	4.89	2.48	3.54	3.76	3.67	8.93	9.42	8.47	--	8.94
Rated	half	2.90	3.60	4.81	4.02	3.84	9.93	6.70	7.14	--	7.92
Rated	full	4.22	6.55	7.67	6.30	6.18	10.8	6.43	6.25	11.5	8.74
		*Onan DJBA					Perkins 4.236				
Idle	0	5.84	6.34	7.41	6.18	6.44	0.83	1.31	0.93	1.41	1.12
Inter.	0	4.56	4.62	4.60	4.18	4.49	0.34	0.86	1.81	1.12	1.26
Inter.	half	3.31	4.43	3.19	3.63	3.64	0.82	1.23	1.61	0.99	1.16
Inter.	full	5.17	4.69	5.33	5.69	5.22	11.7	11.8	11.6	11.3	11.6
Rated	0	5.46	5.46	5.48	5.56	5.49	11.6	9.43	10.0	8.04	9.77
Rated	half	7.75	8.41	9.60	--	8.59	9.03	11.5	7.33	--	9.29
Rated	full	7.96	8.71	7.55	--	8.07	12.4	9.54	11.0	7.24	10.0
		Ford G5000					Hercules G-2300				
Idle	0	2.81	1.26	--	--	2.04	1.09	3.94	3.06	--	2.70
Inter.	0	2.97	2.61	2.73	--	2.77	4.30	2.29	1.82	3.68	3.02
Inter.	half	3.55	3.48	--	--	3.52	1.33	0.90	0.63	1.56	1.10
Inter.	full	2.56	2.60	2.17	2.65	2.50	1.87	1.88	2.00	2.38	2.03
Rated	0	2.52	2.55	--	--	2.54	2.13	1.03	2.30	--	1.82
Rated	half	1.19	1.43	1.49	1.87	1.50	1.58	1.35	2.34	--	1.76
Rated	full	6.27	3.74	4.25	3.72	4.49	1.84	2.66	2.02	2.67	2.30
		J. I. Case 159G					Wisconsin VH4D				
Idle	0	1.07	1.47	1.94	1.99	1.62	3.17	4.58	3.27	3.70	3.68
Inter.	0	0.85	0.87	1.11	1.19	1.01	2.79	4.47	3.98	5.06	5.43
Inter.	half	0.50	0.50	1.06	0.82	0.72	3.78	5.19	3.97	4.36	4.32
Inter.	full	5.57	4.30	4.07	4.51	4.61	5.74	4.00	4.36	2.47	4.14
Rated	0	1.14	0.91	0.70	0.81	0.89	2.87	3.40	2.98	--	3.08
Rated	half	1.00	0.87	0.66	0.84	0.84	2.76	2.58	3.35	3.34	3.01
Rated	full	5.93	3.09	2.95	--	3.99	2.57	3.42	2.47	3.15	2.90

*idle values shown are at low (1000 rpm) idle -- at 1500 rpm (ungoverned idle), values were 3.92, 4.04, 4.46, and 4.20 (average 4.16)

TABLE 23. MASS AND BRAKE SPECIFIC PARTICULATE EMISSIONS FROM F, C, & I ENGINES

Engine		Mass Rate, g/hr	Brake Specific, g/hp hr
Diesels	Allis-Chalmers 3500	66.1	1.23
	Caterpillar D6C	23.2	0.42
	Detroit Diesel 6V-71	16.1	0.21
	International D407	90.6	2.20
	John Deere 6404	91.4	1.89
	Mercedes Benz OM636	20.0	2.22
	Onan DJBA	10.0	2.12
	Perkins 4.236	39.5	1.54
Gasoline	Ford G5000	9.72	0.44
	Hercules G-2300	6.86	0.29
	J. I. Case 159G	5.52	0.41
	Wisconsin VH4D	6.56	0.61

TABLE 24. SUMMARY OF FEDERAL SMOKE TEST RESULTS

Engine	Exhaust Pipe Diameter, in	Smoke Intensity, % Opacity		
		Factor (a)	Factor (b)	Factor (c)
Allis-Chalmers 3500	4*	37.2 (29.5)**	29.7 (23.2)	45.9 (36.9)
Caterpillar D6C	4*	4.7 (3.5)	2.4 (1.8)	8.6 (6.5)
Detroit Diesel 6V-71	4	1.9	1.2	3.5
International D407	4*	17.5 (13.4)	18.8 (14.5)	28.4 (22.2)
John Deere 6404	4*	64.2 (53.7)	25.0 (19.4)	82.4 (72.8)
Mercedes-Benz OM636	2	9.5	10.5	14.0
Perkins 4.236	2	5.6	8.5	10.1

*standard diameter from Federal procedure is 3 inches
**numbers in parentheses corrected to 3 inch diameter by Bouguer's Law

be required for certification of on-road diesel engines beginning with the 1974 model year.

Smoke from the diesel engines was also measured during steady-state conditions, which were the same speed/load conditions used for particulate sampling. Average values for steady-state smoke are given in Table 25, showing an extremely wide range from engine to engine. The condition which produced the greatest smoke intensity from most of the engines was full load at intermediate speed, perhaps not surprisingly since

TABLE 25. AVERAGE STEADY-STATE SMOKE FROM DIESEL ENGINES

		Smoke Intensity in % Opacity at Condition						
			Load at Inter. Speed			Load at Rated Speed		
Engine	Exhaust Pipe Diameter, in.	Low Idle	0	half	full	0	half	full
Allis-Chalmers 3500	4	0.5	1.0	2.8	31.5	1.2	5.0	7.3
Caterpillar D6C	4	2.3	2.0	3.0	4.5	3.2	2.3	2.7
Detroit Diesel 6V-71	4	0.5	0.8	1.0	1.0	1.0	1.0	1.5
International D407	4	1.2	1.0	4.5	20.0	1.0	4.0	9.2
John Deere 6404	4	2.0	1.9	7.3	25.5	2.2	5.5	6.0
Mercedes OM636	2	1.0	1.5	1.5	8.5	2.0	1.5	8.0
Onan DJBA	2	0.5	0.8	2.0	2.5	1.0	1.0	3.0
Perkins 4.236	2	1.0	1.0	1.0	10.3	1.7	1.4	7.7

this point is at a boundary of the operating envelope. The smoke intensities in Table 25 correlate only roughly with the average particulate rates shown in Table 22, yielding an index of determination of 0.66 for the relationship $y \quad -1.04 + 1.11x$, where y is smoke (% opacity) and x is particulate (mg/SCF). The program on which the curve fit was obtained did not include trial of a basic equation of the form predicted by theory ($x \quad A \ln \frac{1}{1-y/100}$), so no index of determination was obtained for that form.

D. Emissions Data from Other Sources

The number of engines tested under the subject program was limited by cost and time considerations, and this restriction was reasonable in view of the relatively low priority that F, C, & I engines have in the total air pollution picture. The rather limited program scope did, however, make it necessary to obtain as much information on engines not tested as possible, and several sources were very helpful(15, 16, 17, 18, 19). Data on diesel engines from all these sources is presented as Table 26, but model designations have been withheld in several instances to avoid releasing confidential data. The weighted averages at the bottom of each category were calculated by weighting the emission data points according to the number of engines represented by each point (assumed to be 1 if number of engines was not available).

TABLE 26. EMISSIONS DATA ON DIESEL ENGINES DEVELOPED BY OTHER SOURCES, BASED ON 13- OR 21-MODE PROCEDURES

Engine		Number of		Brake Specific Emissions, g/hp hr		
Type	Mfr. & Model	Engines	Tests	HC	CO	NO_x
4SNADI	Cat./Ford 1145	5	10	3.09	5.91	11.68
	Cat./Ford 1145	1	N.A.	2.16	7.40	5.52
	Cat./Ford 1150	5	10	3.37	6.62	9.97
	Cummins NH-220	6	N.A.	0.35	9.05	6.71
	Cummins NH-220	1	1	0.36	7.44	8.53
	Cummins V-378	1	1	1.14	6.25	10.76
	Cummins V-504	1	1	1.2	5.70	10.08
	Cummins V-555	1	1	0.90	4.28	7.22
	Cummins V-903	5	10	3.81	5.30	6.81
	Cummins V-903	1	1	0.83	4.37	6.70
	GM DH-478	4	8	2.81	5.59	7.24
	Int. DV550B	1	2	3.52	6.32	8.21
	(Note 1)	6	N.A.	2.33	6.03	11.38
Weighted Averages				2.34	6.41	8.86
4STCDI	Cummins NTC-335	4	8	0.46	2.78	10.21
	Cummins NTC-335	1	1	0.13	2.30	10.39
	Mack ENDT 673B	2	4	2.27	3.25	14.30
	Mack ENDT 675	2	4	1.61	4.80	12.29
	Mack ENDT 675	1	4	1.18	5.37	10.66
	Mack ENDT 864	1	1	2.00	4.47	12.1
	(Note 1)	2	N.A.	2.85	4.40	14.75
	(Note 2)	N.A.	N.A.	1.7	3.4	17.3
Weighted Averages				1.45	3.68	12.43
4SNAPC	(Note 2)	N.A.	N.A.	0.4	2.4	5.6
4STCPC	Cat. 1674	1	6	0.21	1.54	4.82
	(Note 2)	3	N.A.	0.34	2.41	5.91
	(Note 1)	1	N.A.	0.3	2.3	6.1
Weighted Averages				0.31	2.21	5.73
2SBSDI	Det. Die. 6V-53	5	10	1.64	8.76	18.12
	Det. Die. 6V-71	10	20	1.17	9.39	13.91
	Det. Die. 8V-71	5	10	0.82	7.09	16.54
	Det. Die. 8V-71	1	N.A.	2.59	6.58	18.57
	(Note 1)	1	N.A.	0.7	6.1	14.7
Weighted Averages				1.24	8.45	15.71

Note 1: from reference 16
Note 2: withheld to avoid disclosure of confidential information
Abbreviations: 4S and 2S mean 4-stroke and 2-stroke, respectively; NA means naturally aspirated; TC means turbocharged; BS means blower-scavenged; DI means direct injection; PC means pre-combustion chamber injection

The averages were generally quite close to those for similar engine types tested under the contract, as shown in Table 27. Differences which were most significant were NO_x on the 4STCDI category, and in this case the engines tested under the program simply emitted relatively low NO_x. Both CO and NO_x showed considerable differences for the 2SBSDI category (Detroit Diesel engines), in this case presumably due to the use of older injection systems in some of the engines from which the "other sources" data were obtained. Since the correlation between data obtained under the subject contract and those obtained from outside sources is reasonably good, the former will be used in computing factors and impact except where such use would compromise accuracy. The reason for preference of data developed under this program is simply that it is fully documented, whereas some of the other data must be accepted at face value with little knowledge of how it was obtained.

TABLE 27. AVERAGE BRAKE SPECIFIC EMISSIONS FROM DIESELS BY ENGINE TYPE, TEST ENGINES COMPARED TO DATA FROM OTHER SOURCES

	HC, g/hp hr		CO, g/hp hr		NO_x, g/hp hr	
Engine Type	Test Data	Outside Data	Test Data	Outside Data	Test Data	Outside Data
4SNADI	1.68	2.34	6.16	6.41	9.44	8.86
4STCDI	2.18	1.45	4.62	3.68	8.64	12.43
4SNAPC	1.55	0.4	5.65	2.4	4.98	5.6
4STCPC	0.12	0.31	1.13	2.21	5.19	5.73
2SBSDI	0.70	1.24	2.96	8.45	20.2	15.71

V. ESTIMATION OF EMISSION FACTORS AND NATIONAL IMPACT FOR HEAVY-DUTY ENGINES USED IN FARM APPLICATIONS

This report section will treat farm engines as a category apart from the construction category and the industrial category. The idea behind this approach is that emission results for all three categories should be drawn from as many sources as possible, but that emission factors and impact estimates should be treated separately due to differences in duty cycles and makeup of the categories with regard to engine type and size. Sections VI and VII will treat construction and industrial engines, respectively.

A. Analysis of Population and Usage for Heavy-Duty Farm Engines

In contrast to several of the other engine categories being studied under the subject contract, a good deal of information is available on farm equipment production and population[20, 21]. Some of these statistics are presented in Table 28, and they form the basis for the farm tractor population analysis which is a necessary input to emission factor computation. The major items of information which do not appear to be available in published statistics are the sizes and types (gasoline and diesel) of machines which constitute the present population, so estimates will have to be made based on the data in Table 28 and some reasonable assumptions. Wheel tractors will be handled first, and other farm machinery afterward.

The most complex problem requiring solution in order to get a true picture of the present population is selection of a mathematical population model which is consistent with known facts. That is, it is necessary to know how many units produced in each of the prior years is still in service in 1972, because this knowledge will lead to accurate breakdowns by engine size and by type of fuel used. The function used to attempt a definition of the farm tractor population was

$$F_i = S_i/N_i \quad e^{-kA_i^n}$$

where S_i = number of units surviving in 1972 out of the N_i units produced in year i (age = A_i), k = $1/A_c^n$, and n = an exponent greater than zero. The constant A_c is called the "characteristic age", and both it and the exponent "n" must be determined by trial and error. If a value for n is assumed first, successive approximation will yield a value for k = $1/A_c^n$ to complete the relationship

$$\sum_{i=0}^{i=52} S_i = \sum_{i=0}^{i=52} N_i e^{-kA_i^n} = 4.469\times10^6 \text{ (1972 population)}$$

This equation is the "first check", assuring that the selected function will in

TABLE 28. DATA ON THE U.S. FARM WHEEL TRACTOR POPULATION

Year	Age $= A_i$	Sales = N_i, Units $x10^{-3}$	Total Units in Use $x10^{-3}$	Avg. Wheel Tractor PTO hp Sold	Avg. Belt hp in Use	% Wheel Tractors Sold	
						Gasoline	Diesel
1972	0	157	4469	-	-	-	-
1971	1	132	4562	76.6	45.2	24.3	75.7
1970	2	136	4619	72.4	45.0	28.5	71.5
1969	3	144	4712	72.8	42.2	30.2	69.0
1968	4	158	4766	69.5	40.8	29.1	69.3
1967	5	177	4786	68.2	39.3	33.3	65.5
1966	6	185	4783	65.9	38.2	39.8	58.1
1965	7	162	4787	63.1	36.7	40.6	56.6
1964	8	157	4786	59.3	35.8	42.2	54.1
1963	9	155	4778	57.5	34.8	47.2	48.5
1962	10	153	4763	55.3	33.9	52.9	42.7
1961	11	138	4743	51.6	33.0	49.1	46.8
1960	12	124	4688	47.7	32.6	55.4	40.8
1959	13	215	4673	45.6	31.3	64.6	30.6
1958	14	194	4620	45.9	30.5	71.7	23.2
1957	15	186	4570	44.9	29.7	78.2	16.3
1956	16	167	4480	41.0	29.3	82.5	12.5
1955	17	268	4345	39.8	29.0	83.9	12.6
1954	18	203	4243	38.8	28.3	86.7	11.4
1953	19	315	4100	34.8	28.0	93.1	5.6
1952	20	334	3907	30.9	27.7	94.3	5.7
1951	21	442	3678	29.4	27.6	-	-
1950	22	402	3399	29.0	27.4	-	-
1949	23	430	3123	28.4	-	-	-
1948	24	422	2821	27.0	-	-	-
1947	25	334	2613	26.1	-	-	-
1946	26	197	2480	26.2	-	-	-
1945	27	171	2354	26.6	-	-	-
1944	28	220	2215	27.4	-	-	-
1943	29	101	2100	27.6	-	-	-
1942	30	152	1885	-	-	-	-
1941	31	256	1675	-	-	-	-
1940	32	206	1545	-	-	-	-
1939	33	166	1445	-	-	-	-
1938	34	166	1370	-	-	-	-
1937	35	166	1230	-	-	-	-
1936	36	166	1125	-	-	-	-
1935	37	145 [a]	1048	-	-	-	-
1934	38	22 [a]	1016	-	-	-	-
1933	39	0 [a]	1019	-	-	-	-
1932	40	0 [a]	1022	-	-	-	-
1931	41	47 [a]	997	-	-	-	-
1930	42	145 [a]	920	-	-	-	-
1929	43	140	827	-	-	-	-
1928	44	140	782	-	-	-	-
1927	45	140	693	-	-	-	-
1926	46	140	621	-	-	-	-
1925	47	140	549	-	-	-	-
1924	48	100 [a]	496	-	-	-	-
1923	49	128 [a]	428	-	-	-	-
1922	50	105 [a]	372	-	-	-	-
1921	51	55 [a]	343	-	-	-	-
1920	52	182 [a]	246	-	-	-	-

[a] estimated from change in population for following year

fact compute the correct present population when applied to known sales data. The next step is to apply the same model to previous years and determine whether or not it still calculates the correct number. Some of the models tried are plotted in Figure 21, to show the effect of variation in the exponent n.

Intuitively, the curves for n=2 and n=3 seem to approximate the fraction of wheel tractors surviving in the expected way, but mathematical checks are a more accurate way of determining the correctness of the models. The two checks employed were (1) calculation of populations for prior years based on the survival models with comparison to known values, and (2) calculation of average horsepower of tractors in the field with checks against a known value. The results of these checks are shown in Table 29, and it is apparent that none of the models is without flaws. The model with n = 1 calculates both population and horsepower values which are too low, and the model with n = 3 calculates very high populations and a slightly low horsepower value. The model with n = 2 calculates moderately high populations

TABLE 29. COMPARISON OF DATA CALCULATED BY SURVIVAL MODELS TO KNOWN FACTS ABOUT THE FARM WHEEL TRACTOR POPULATION

Statistic	Known Value	Percentage Prediction Error for Model		
		n=1, Ac=27.55	n=2, Ac=25.40	n=3, Ac=24.54
1972 Tractor Population	4.469×10^6	+0.1	+0.2	0.0
1965 Tractor Population	4.787×10^6	-5.7	+1.4	+4.8
1960 Tractor Population	4.688×10^6	-2.4	+8.3	+11.6
1971 Average Horsepower	45.2	-12.3	-5.5	-3.3

and a moderately low horsepower value. Conceding that it is a compromise the model with n = 2 will be used to determine the age distribution of tractors in use. Calculations with this model lead to an average age for tractors in use of about 15 years, and an average service life of about 22 years, both of which seem quite reasonable in light of available information. The average age is

$$\bar{A} = \frac{\sum_{i=0}^{i=52} S_i A_i}{\sum_{i=0}^{i=52} S_1},$$ and the average service life is calculated by

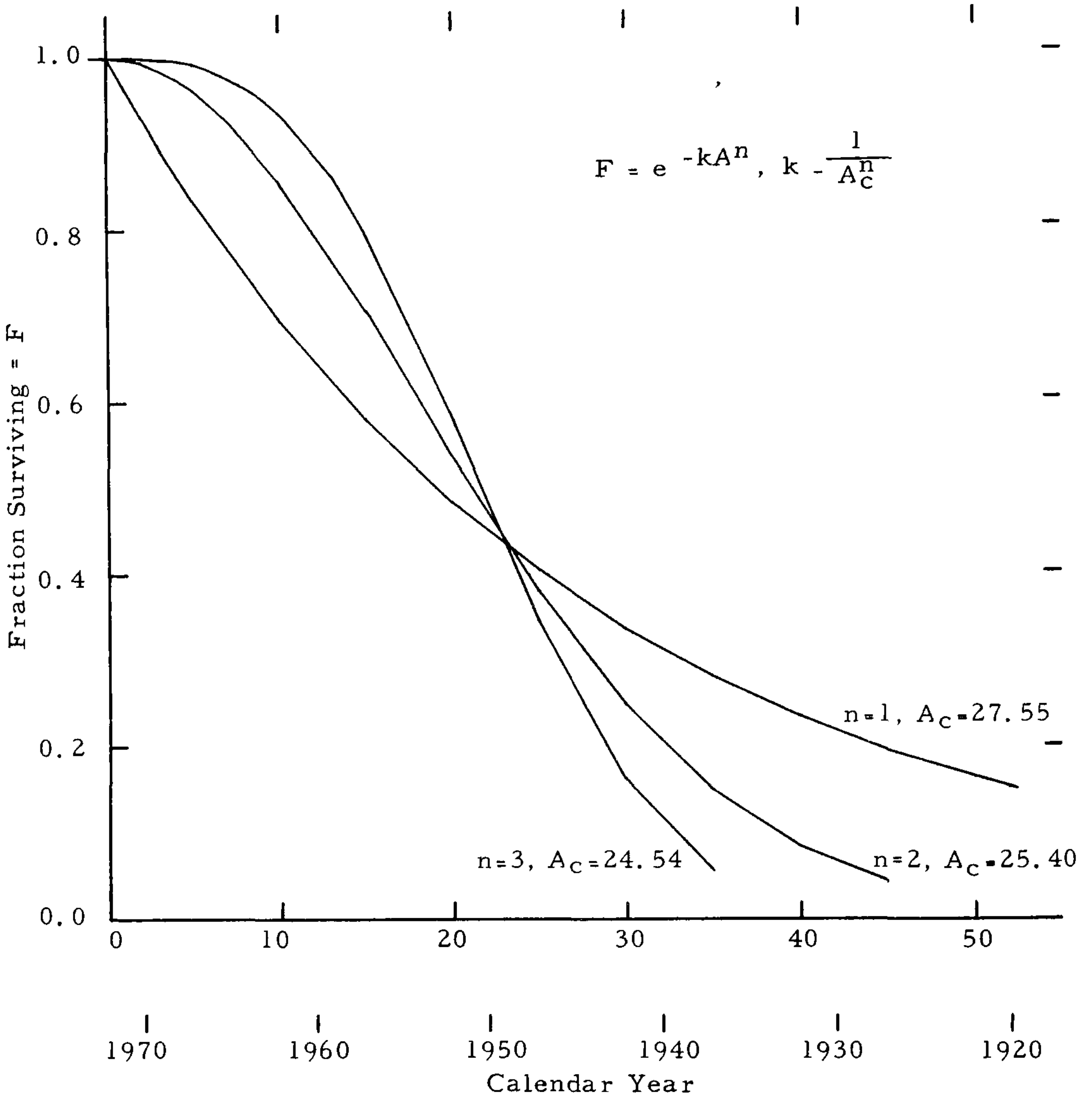

FIGURE 21. EXPERIMENTAL POPULATION MODELS FOR FARM TRACTORS

$$\bar{A}_R = \sum_{i=1}^{52} (A_i)(F_{i-1} - F_i)$$

The values apply only to the population at the end of 1972, structured as assumed by n=2, A_c=25.40.

In order to arrive at accurate emission factors for tractors, it is also necessary to determine the fraction of the present population powered by diesel engines (as opposed to gasoline engines). This task would not be so difficult if average power and fraction of tractors sold with diesel engines had been relatively constant in the past, but over the past 20 years the average horsepower of tractors sold has more than doubled, and the market share of diesels has risen from essentially zero to more than 75%. As a minimum, it is necessary to determine the fraction of each power category equipped with diesel engines for each year over which data are available.

Performing such a calculation requires a set of assumptions based on the best available information, and if the assumptions are reasonable, then the calculated overall percentage of each year's production powered by diesels should be the same as the known value. The basic data on production by power category are given in Table 30[20], and a set of assumptions which permit computation of the fraction of diesel-powered tractors in each model year/ power classification is summarized below. These assumptions are based on

1. 100% of tractors produced having 80 PTO hp or more were diesels

2. in the size range 35 to 79 hp, and for the years 1962-1971,

   $$\% \text{ diesels} - \left[45 + 0.47 \text{ (median hp in category)}\right] \left(\frac{\text{model year} \quad 1952}{20}\right)$$

3. in the size range 35 hp and up, and for the years 1952-1961

   $$\% \text{ diesels} = 100 \left(\frac{\text{model year} \quad 1952}{20}\right)$$

4. 10% of tractors produced having less than 35 PTO hp were diesels

the ideas that very large tractors are predominantly diesel, that very small tractors are predominantly gasoline, and that the percentage of diesels in the mid-size ranges varies directly with power output and the number of years since the diesel market percentage was essentially zero. The overall

TABLE 30. CLASSIFICATION OF FARM TRACTOR PRODUCTION BY PTO HORSEPOWER, 1952 THROUGH 1971

Year	Percent of Market by PTO Horsepower Class[20]												
	to 34	35-39	40-49*	50-59*	60-69	70-79*	80-89	90-99*	100-109*	110-119	120-129	130-139	140 up
1971	6.5	14.9	4.5	12.1	11.2	5.1	3.2	17.4	6.0	8.9	1.9	6.2	1.9
1970	5.8	17.7	4.0	13.0	13.9	5.7	3.9	17.2	8.5	3.5	2.9	3.0	1.0
1969	5.6	16.0	4.7	13.3	14.4	7.3	3.3	18.1	17.3	-	-	-	-
1968	6.2	16.0	6.2	14.0	12.4	9.2	3.1	23.7	9.2	-	-	-	-
1967	6.3	15.9	8.2	14.0	11.0	10.2	3.7	23.1	7.6	-	-	-	-
1966	5.1	15.9	10.1	14.1	16.6	6.2	4.3	22.2	5.5	-	-	-	-
1965	7.2	15.4	12.9	9.5	17.1	9.6	3.6	22.5	2.3	-	-	-	-
1964	12.2	13.5	17.3	12.8	14.0	8.7	4.4	15.0	2.1	-	-	-	-
1963	13.2	11.8	22.5	11.9	15.3	15.7		9.6	-	-	-	-	-
1962	12.0	17.7	20.0	15.1	17.2	18.0	-	-	-	-	-	-	-
1961	12.2	36.8		60.0	-	-	-	-	-	-	-	-	-
1960	16.9	36.9		46.2	-	-	-	-	-	-	-	-	-
1959	22.8	34.5		42.6	-	-	-	-	-	-	-	-	-
1958	21.1	40.9		38.0	-	-	-	-	-	-	-	-	-
1957	28.9	42.2		28.8	-	-	-	-	-	-	-	-	-
1956	34.5	45.2		20.2	-	-	-	-	-	-	-	-	-
1955	35.8	45.3		18.9	-	-	-	-	-	-	-	-	-
1954	48.4	37.5		14.1	-	-	-	-	-	-	-	-	-
1953	62.2	15.1		22.6	-	-	-	-	-	-	-	-	-
1952	77.4	22.6		-	-	-	-	-	-	-	-	-	-

*Values in these columns which terminate lines are understood to include all higher horsepower values not classified for those years.

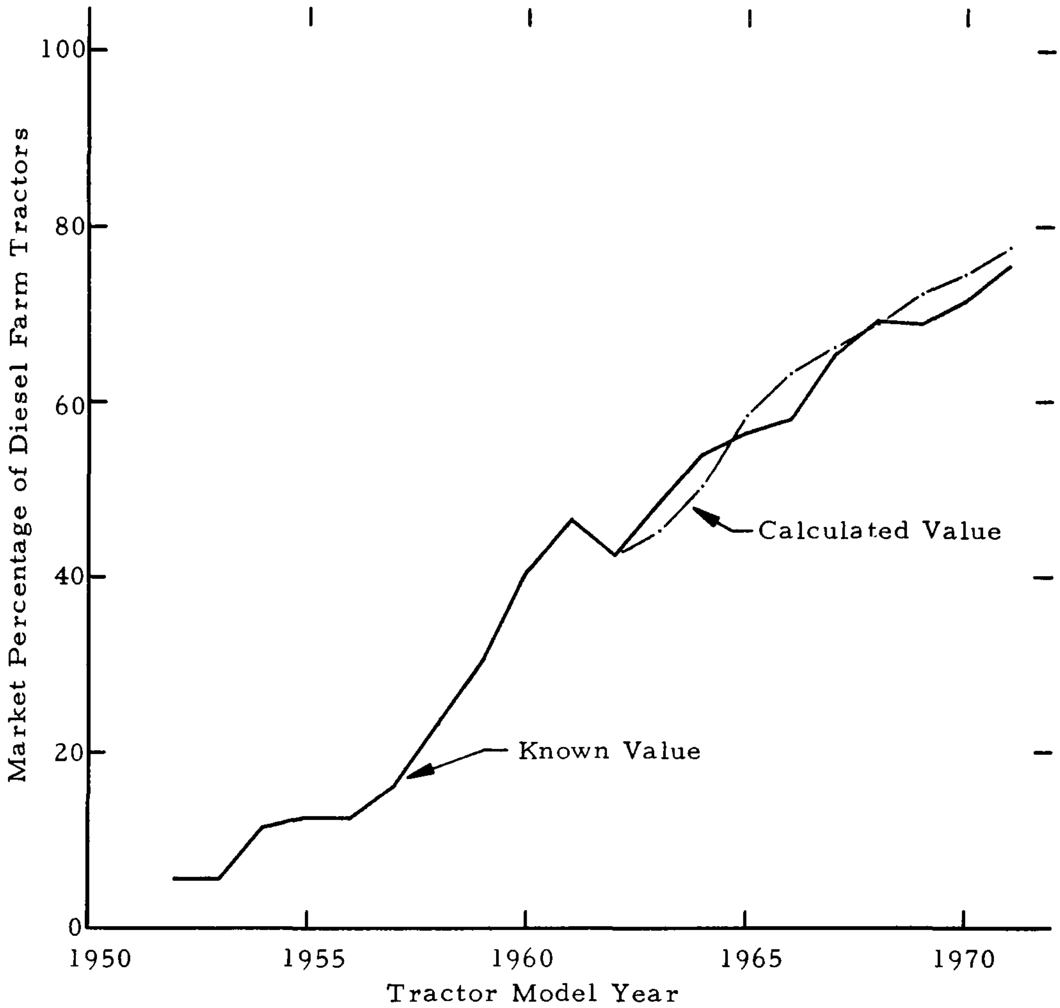

FIGURE 22. COMPARISON OF KNOWN AND CALCULATED VALUES FOR MARKET PERCENTAGE OF DIESEL FARM TRACTORS, 1950 THROUGH 1971

percentages of production using diesel engines calculated on the basis of the assumptions (1971-1963) are not exactly the same as the known figures, but are reasonably close, as shown in Figure 22. Now if it is further assumed that the mean PTO horsepower for gasoline and diesel engines is the same within each power category, it becomes possible to estimate the overall percentage of farm tractor horsepower which is diesel and that which is gasoline.

The mean PTO horsepower for tractors sold in each power category back to 1964[20] is given in Table 31, along with the values which will be used for calculations in earlier years leading to an estimate of the present population. For earlier years, it is also necessary to assume values for categories such as "90 hp and up", "70 hp and up", and so forth. In each case, the value assumed for these latter categories is 10 horsepower above the lower boundary of the category. Although it is probably a weak assumption, it will also be assumed that the average service life of diesel and gasoline tractors in all power categories is the same.

TABLE 31. MEAN FARM TRACTOR PTO HORSEPOWER BY POWER CATEGORY FOR 1964-1971[20]

Hp Class	Mean PTO Horsepower by Year								Assumed for Earlier Years' Calculations
	1964	1965	1966	1967	1968	1969	1970	1971	
up to 35	30.0	30.0	32.0	32.0	30.5	30.8	30.8	31.0	30
35-39	37.0	37.0	38.0	38.5	37.5	38.0	37.5	38.0	37
40-49	45.1	45.0	46.0	46.0	46.5	46.5	45.0	43.3	45
50-59	57.7	55.0	54.0	56.0	55.0	53.5	55.0	53.0	55
60-69	65.1	65.0	65.0	65.5	66.0	66.8	65.0	65.0	65
70-79	76.4	73.2	74.0	75.0	76.0	76.0	75.0	73.5	75
80-89	85.0	87.0	87.0	87.0	87.0	86.1	85.0	85.0	85
90-99	91.9	92.0	92.0	92.5	94.6	94.9	95.0	94.0	95
100 & up	105.1	105.0	118.0	119.0	111.7	118.1	117.7	121.3	

Based on all the foregoing discussion and qualifications, Table 32 presents an estimate of the structure of the farm tractor population as of December 31, 1972. Summing the columns on the right yields approximately 206×10^6 tractor PTO hp in use, with 111×10^6 hp in gasoline engines and 95.4×10^6 hp in diesels. A comparable estimate of total hp in use based on U.S. Statistical Abstracts is also 206×10^6 hp[21]. Using data from Table 32, the average PTO horsepower of gasoline farm tractors is calculated to be 35.6 hp, and that for diesels is calculated to be 69.7 hp. These summaries pertain only to tractor hp in the field, and probably do not represent the correct ratio of horsepower-hours used because usage undoubtedly varies with both machine size and age.

TABLE 32. ESTIMATED STRUCTURE OF THE FARM TRACTOR POPULATION AS OF 12/31/72

Year	Units Surviving x 10^{-3}			Hp of Units Surviving x 10^{-6}		
	Total	Gasoline	Diesel*	Total	Gasoline	Diesel
1972**	157	31	126	12.2	1.22	11.0
1971	132	32	100	10.1	1.31	8.80
1970	135	38	97	9.77	2.03	7.74
1969	142	43	99	10.3	1.86	8.41
1968	154	45	109	10.7	2.25	8.45
1967	170	57	113	11.6	2.81	8.79
1966	175	70	105	11.5	3.08	8.42
1965	150	61	89	9.47	2.93	6.54
1964	142	60	82	8.42	3.20	5.22
1963	137	65	72	7.88	3.43	4.45
1962	131	69	62	7.24	3.83	3.41
1961	114	56	58	5.88	2.89	2.99
1960	99	55	44	4.72	2.61	2.11
1959	165	107	58	7.52	4.86	2.66
1958	143	103	40	6.56	4.70	1.86
1957	131	102	29	5.88	4.60	1.28
1956	112	92	20	4.59	3.79	0.80
1955	171	143	28	6.81	5.71	1.10
1954	123	107	16	4.77	4.14	0.63
1953	188	168	12	6.26	5.83	0.43
1952	180	170	10	5.56	5.24	0.32
1951	223	223	-	6.56	6.56	-
1950	190	190	-	5.51	5.51	-
1949	189	189	-	5.37	5.37	-
1948	173	173	-	4.67	4.67	-
1947	127	127	-	3.31	3.31	-
1946	69	69	-	1.81	1.81	-
1945	55	55	-	1.46	1.46	-
1944	65	65	-	1.78	1.78	-
1943	27	27	-	0.75	0.75	-
1942	38	38	-	0.95	0.95	-
1941	58	58	-	1.45	1.45	-
1940	42	42	-	1.05	1.05	-
1939	31	31	-	0.62	0.62	-
1938	28	28	-	0.56	0.56	-
1937	25	25	-	0.50	0.50	-
1936	22	22	-	0.44	0.44	-
1935	17	17	-	0.34	0.34	-
1934	2	2	-	0.04	0.04	-
1933	0	0	-	0.00	0.00	-
1932	0	0	-	0.00	0.00	-
1931	3	3	-	0.06	0.06	-
1930	9	9	-	0.18	0.18	-
1929	8	8	-	0.16	0.16	-
1928	7	7	-	0.14	0.14	-
1927	6	6	-	0.12	0.12	-
1926	5	5	-	0.10	0.10	-
1925	5	5	-	0.10	0.10	-
1924	3	3	-	0.06	0.06	-
1923	3	3	-	0.06	0.06	-
1922	0	0	-	0.00	0.00	-
1921	1	1	-	0.02	0.02	-
1920	3	3	-	0.06	0.06	-

* includes LPG-powered units, estimated to total about 4% of the population
**estimated

Compared to that for farm tractors, only a small amount of information is available on other heavy-duty engines used on farms. The major uses of these engines other than tractors include self-propelled combines and forage harvesters, and engines used on irrigation pumps and as auxillary engines on pull-type combines and balers. A tabulation of engine applications and some characteristics of the machines which will be assumed typical for the purposes of this report is given in Table 33. It is conceded that these assumptions have little basis except availability of the machines in the current market[20], but such estimates are necessary in lieu of comprehensive data. Summing the estimated horsepower of tractors and other powered farm machines yields approximately 319×10^6 hp, which compares quite well with the 301×10^6 hp figure from Statistical Abstracts[24].

Having arrived at a structure for the population of heavy-duty engines used in farm applications, the next step is to determine representative annual usage rates for the various categories of machines. Once again, the best data available are on tractors, with one broadband estimate of 550 hours per year for "grain belt" usage[23]. Another estimate is "almost a linear relationship to tractor horsepower ranging from 450 hr for a 50 hp tractor to 800 hr for a 140 hp tractor"[23], or in other words, usage in hours $\approx 450 + 3.89$ (hp-50). The latter estimate weights usage somewhat more heavily toward newer tractors, since the newer units have higher average power ratings, but it is

TABLE 33. APPLICATIONS OF HEAVY-DUTY ENGINES ON FARMS (OTHER THAN TRACTORS) AND ASSUMED CHARACTERISTICS OF THE APPLICATIONS

	Application					
	Combine, Self-Propelled	Combine, Pull Type	Corn Pickers & Picker-Shellers	Pick-up Balers	Forage Harvesters	Other (Misc)
Units in service $\times 10^{-3}$ [20]	434	289	687	655	295	1205
% using engines	100	25	-	50	10	100
Typical size	14 ft	8 ft	2-row	6 ton/hr	12 ft or 3-row	-
Typical hp	110	25	-	40	140	30
% gasoline	50	100	-	100	0	50
% diesel	50	0	-	0	100	50

based on relatively new (in-warranty) units. To account for decreased usage with age, the further assumption will be made that usage decreases linearly with age to 50 hours per year for the few 1920 model units still in service. The complete usage equation can then be written

$$(\text{usage in hours})_i = 450 + 3.89\ (hp_i - 50) - 5.45\ (A_i)$$

for any year, and the average usage (separately for gasoline and diesel units) is calculated by

$$\text{average usage in hr/yr} = \frac{450\ (53) + \sum_{i=0}^{52} 3.89\ (hp_i - 50) - 5.45\ (A_i)}{\text{Number of Units in Service}}$$

This computation yields mean usages of 490 hours/year for diesel tractors and 291 hours/year for gasoline tractors. One independent appraisal of the accuracy of these estimates can be obtained using data from yet another source(25). These data indicate that the annual usage of tractors is quite heavily weighted in the direction of newer models, as shown in the second column of Table 34. Using average horsepower sold (Table 28)

TABLE 34. TWO INDEPENDENT ESTIMATES OF ANNUAL USAGE OF TRACTORS AS A FUNCTION OF TRACTOR AGE

Tractor Age, up to (years)	Percent Total Tractor Hours Used by Age Group: First Estimate(25)	Percent Total Tractor Hours Used by Age Group: Calculated from Tables 28 and 32 (and Usage Equation Above)
2	8	12.4
5	25	27.0
9	50	45.2
16	75	66.9
27	95	95.4

and units surviving (Table 32) in conjunction with the power-age-usage relationship presented above, the figures in the third column of Table 34 were calculated for comparison. Part of the disagreement for the younger groups of tractors may be due to inconsistency in the definition of tractor age (for example, the "first estimate" may assume that only tractors of age 1 are included in the "up to 2" category, whereas the calculated values assume that all tractors up to and including age 2 are covered by the "up to 2" category). In any case, the two age-usage relationships are quite similar overall, and the usage estimate resulting in the calculated values described above (third column of Table 34) will be assumed adequate for the purposes of this report.

Annual usage of other farm implements which employ heavy-duty engines is not as readily available as that for tractors, so a different approach will be used to estimate their annual operating time. Usage of specific-purpose implements is controlled primarily by total crop acreage for which they are required, and documentation of acreage is available(24). Table 35 shows acreage of major crops(24) harvested by the machines listed in Table 33, as well as estimates of total machine hours required for harvesting by powered and non-powered machines(26). Summing the operating hours for the machine categories (with

TABLE 35. MAJOR U.S. CROP ACREAGE (1970) AND ESTIMATED MACHINE HOURS REQUIRED FOR HARVESTING[24, 26]

Crop	U.S. Acreage $x10^{-6}$	Powered Machine & Required hours $x10^{-6}$	Non-Powered Machine & Req'd. hours $x10^{-6}$
Corn	57.4	pull combine - 0.76 s-p combine - 6.45	corn-picker - 19.1 pull combine - 2.28
Wheat	44.3	pull combine 1.17 s-p combine - 9.96	pull combine - 3.51
Oats	18.6	pull combine - 0.49 s-p combine - 4.18	pull combine 1.48
Sorghum	13.8	pull combine - 0.37 s-p combine - 3.10	pull combine 1.10
Barley	9.6	pull combine - 0.25 s-p combine 2.16	pull combine 0.76
Rye	1.5	pull combine - 0.04 s-p combine 0.34	pull combine 0.12
Other Grains, Seeds, & Legumes	*25	pull combine - 0.66 s-p combine - 5.62	pull combine - 1.98
Hay, Straw, & Forage	**70	pick-up baler 7.83 forage harvester-3.53	pick-up baler - 7.83 forage harvester-3.53

*only that portion of crops assumed harvested by combine is listed
**assuming 80% of hay acreage is baled or cut by field forage harvesters, and that $17.8x10^6$ acres of straw or other forage is harvested.

engines), pull combines account for about $3.74x10^6$ hours per year, self-propelled combines for about $31.8 x10^6$, balers for about $5.22x10^6$, and self-propelled forage harvesters account for about $3.53x10^6$ hours annually. These figures translate into annual usage per (motorized) machine of 52 hours for pull-type combines, 73 hours for self-propelled combines, 24 hours for balers, and 120 hours for self-propelled forage harvesters. All these annual usage figures seem low from an economic standpoint, so the situation must be that a wide range of usage occurs for each type of machine, depending on farm size and use of custom operations.

No data are available on the miscellaneous (Table 33) heavy-duty engines used on farms, although their existence is documented by census figures (24). For the purposes of this report, usage of these engines will be assumed to average 50 hours per year, which is about the minimum usage which would justify having the engine at all. It is assumed that the miscellaneous engines include irrigation pump engines (which would have high usage), and those used on welders, large compressors, and auxillary generators (which probably have low usage).

B. Development of Emission Factors for Farm Engines

Having compiled estimates for the population and annual usage of heavy-duty farm engines in the previous section, it now becomes necessary to assign emission factors to that population. This task requires examination of farm engine duty cycles to determine how the mode emissions data in Section IV should be weighted for each application, and it requires the determination of which test engines should be assumed to represent each application. The first part of this task was referred to in section II, Objectives, as a modification of the calculation procedures already discussed in sections III. C. and IV. A. Fortunately, there is a good representation of farm engines among the test engine group, with at least 5 of the 8 diesels and 3 of the 4 gasoline engines tested being used in farm equipment.

Farm tractor duty cycles have been researched by several investigators for different purposes (23), and the results of some of these studies are shown in Table 36. In addition, a "consensus" weighting factor schedule is given in Table 36, differing only slightly from the average of factors from sources A through D. This "consensus" schedule will be used to recompute cycle composite brake specific emissions from the test engines which are used in the farm tractor application. Most of the mode emissions data were generated on 21-mode (or 23-mode for gasoline engines) procedures, or in the case of particulate, on procedures having only 7 modes. Weighting factors for the procedures having 21 (23 for gasoline engines) or 7 modes (derived from the ones given above for the 13-mode procedure) are shown in Table 37. These factors yield a composite load factor of about 0.57 for farm tractors, which is somewhat higher than that for many other applications of heavy-duty engines. Since no data are available on the normal speed-load schedule of heavy-duty farm engines used in applications other than tractors, the factors shown in the four right-hand columns of Table 37 will be used. These factors are based on the ideas that most non-tractor farm engines are governed at or near rated speed, and that they spend little time at idle. The composite load factor resulting from these latter weighting factors is about 0.52, which is lower than that for tractors but higher than that expected for on-road engine usage. Note also that the closed-throttle modes (12 and 23) of the gasoline schedule have been given zero weight because they are assumed largely inapplicable to farm operation.

TABLE 36. FARM TRACTOR MODE WEIGHTING FACTORS FOR THE 13-MODE GASEOUS EMISSIONS PROCEDURE[21, 23]

Mode(s)	Mode Weighting Factors by Source: Source A	Source B	Source C	Source D	Consensus For Report
1+7+13	0.079	0.058	0.07	0.00	0.06
2	0.022	0.057	0.01	0.00	0.03
3	0.059	0.092	0.02	0.0014	0.05
4	0.060	0.076	0.035	0.0040	0.05
5	0.056	0.061	0.40	0.0956	0.11
6	0.005	0.021	0.00	0.0127	0.01
8	0.158	0.132	0.00	0.0249	0.10
9	0.256	0.205	0.40	0.4395	0.32
10	0.160	0.151	0.035	0.3519	0.17
11	0.097	0.113	0.02	0.0231	0.06
12	0.048	0.034	0.01	0.0469	0.04

Sources:
A. general corn & grain use - Agricultural Engineering, Feb. 1969
B. general farm use - John Deere data
C. Allis-Chalmers data
D. Detroit Diesel - Allison data - hard plowing alfalfa

To arrive at cycle composite gaseous emissions with mode weighting factors as described in Tables 36 and 37, the average mode mass emissions from Tables 8-19 were used rather than going back to each individual run. Particulate emissions were computed in the same way, using data on individual mode mass emissions which do not appear explicitly in the report. Composite mass and brake specific NO_x emissions were corrected for humidity using the factors given in section III. C. These reweighted composite data are given in Table 38 for both farm tractor and farm non-tractor applications. The engines omitted from the tractor weighting schedule (Cat. D6-C, M-B OM636, Onan DJBA, Herc. G-2300, and Wisc. VH4D) are assumed not to be used in farm tractors, so their emissions will not be used in computing emission factors for farm tractor applications.

Having developed brake specific emissions for a number of farm tractor and farm non-tractor engines, it remains to combine them in such a way that they form a reasonable representation of machines used in the field. This task requires the assumption of a fraction of total diesel tractor horsepower hours for each of the five diesels listed at the top of Table 38, and corresponding assumptions for the two gasoline engines used in tractor service. It further requires the assumption of fractions of total non-tractor horsepower hours for all 12 engines

TABLE 37. FARM TRACTOR MODE WEIGHTING FACTORS FOR THE 21-MODE (23 FOR GASOLINE ENGINES) PROCEDURE AND THE (SPECIAL 7-MODE) PARTICULATE MEASUREMENT PROCEDURE

	Tractor Mode Weighting Factors by Procedure			Weighting Factors by Procedure for Applications other than Tractors			
Mode	Particulate*	21-Mode	23-Mode**	Particulate*	13-Mode	21-Mode	23-Mode**
1	0.06	0.02	0.02	0.04	0.0133	0.0133	0.0133
2	0.055	0.0225	0.0225	0.06	0.035	0.02	0.02
3	0.13	0.02	0.02	0.09	0.04	0.02	0.02
4	0.065	0.025	0.025	0.09	0.055	0.02	0.02
5	0.07	0.025	0.025	0.12	0.055	0.03	0.03
6	0.36	0.025	0.025	0.42	0.055	0.03	0.03
7	0.26	0.04	0.04	0.18	0.0133	0.03	0.03
8	-	0.055	0.055	-	0.11	0.03	0.03
9	-	0.03	0.03	-	0.16	0.03	0.03
10	-	0.0075	0.0075	-	0.25	0.03	0.03
11	-	0.02	0.02	-	0.13	0.0133	0.0133
12	-	0.075	0.00	-	0.07	0.06	0.00
13	-	0.105	0.075	-	0.0133	0.06	0.06
14	-	0.16	0.105	-	-	0.06	0.06
15	-	0.1225	0.16	-	-	0.14	0.06
16	-	0.085	0.1225	-	-	0.14	0.14
17	-	0.0575	0.085	-	-	0.14	0.14
18	-	0.03	0.0575	-	-	0.04	0.14
19	-	0.025	0.03	-	-	0.04	0.04
20	-	0.03	0.025	-	-	0.04	0.04
21	-	0.02	0.03	-	-	0.0133	0.04
22	-	-	0.02	-	-	-	0.0133
23	-	-	0.00	-	-	-	0.00

*sequence of conditions as shown in Table 22
**sequence as shown in Table 2

TABLE 38. COMPOSITE MASS AND BRAKE SPECIFIC EMISSIONS FOR TEST ENGINES WEIGHTED TO SIMULATE FARM TRACTOR AND FARM NON-TRACTOR APPLICATIONS

Engine	Mass Emissions in g/hr, Tractor Weighting						Specific Emissions in g/hphr, Tractor Weighting					
	HC	CO	NO_x	RCHO	SO_x	Particulate	HC	CO	NO_x	RCHO	SO_x	Particulate
Allis-Chalmers 3500	40.7	214.	874.	13.	70.5	64.5	0.505	2.66	10.8	0.16	0.875	0.792
Detroit Dies. 6V-71	69.5	168.	2630.	12.	102.	21.9	0.615	1.49	23.3	0.11	0.903	0.195
International Har. D407	136.	284.	518.	9.0	52.4	108.	2.23	4.67	8.51	0.15	0.862	1.77
John Deere 6404	216.	196.	432.	64.	67.1	91.3	2.93	2.66	5.86	0.88	0.910	1.22
Perkins 4.236	15.8	130.	432.	7.8	32.2	57.2	0.392	3.22	10.7	0.19	0.799	1.42
Ford G5000	202.	4860.	269.	11.	8.62	13.6	5.36	129.	7.14	0.28	0.229	0.355
J. I. Case 159G	150.	5980.	49.4	11.	6.05	6.86	6.73	268.	2.22	0.50	0.271	0.307

Engine	Mass Emissions in g/hr, Farm Non-Tractor Weighting						Specific Emissions in g/hphr, Farm Non-Tractor Weighting					
	HC	CO	NO_x	RCHO	SO_x	Particulate	HC	CO	NO_x	RCHO	SO_x	Particulate
Allis-Chalmers 3500	39.8	231.	780.	12.	65.3	67.3	0.550	3.19	10.8	0.16	0.905	0.902
Caterpillar D6C	6.88	66.3	353.	6.3	64.0	30.6	0.093	0.897	4.78	0.084	0.866	0.404
Detroit Diesel 6V-71	71.3	183.	2380.	12.	93.8	21.3	0.706	1.81	23.5	0.12	0.929	0.207
International Har. D407	136.	304.	449.	10.	49.0	106.	2.49	5.56	8.22	0.19	0.897	1.90
John Deere 6404	213.	198.	368.	57.	62.7	91.2	3.21	2.98	5.54	0.86	0.944	1.34
Mercedes-Benz OM636	15.2	55.6	42.2	3.4	16.3	26.9	1.03	3.76	2.85	0.26	1.10	2.01
Onan DJBA	9.59	26.4	39.8	1.0	8.30	13.4	1.50	4.13	6.23	0.16	1.30	2.08
Perkins 4.236	17.4	137.	354.	9.4	29.6	59.7	0.428	3.81	9.83	0.26	0.823	1.63
Ford G5000	200.	4870.	232.	10.	8.07	11.4	5.91	144.	6.85	0.30	0.238	0.327
Hercules G2300	214.	6820.	141.	5.9	9.23	8.82	5.96	190.	3.93	0.16	0.257	0.240
J. I. Case 159G	154.	5770.	44.5	11.	5.77	6.01	7.66	287.	2.21	0.55	0.287	0.293
Wisconsin VH4D	137.	4330.	80.0	2.1	5.02	7.89	9.26	293.	5.41	0.14	0.339	0.512

with emissions computed on the farm non-tractor operating schedule (bottom of Table 38). Without question these assumptions will be arbitrary, but lacking a complete census of engines in the field, they are necessary. The assumptions made for the purpose of this report are listed in Table 39, along with the contribution of each engine to the composite factors and the composite factors themselves. The composite emission factors thus generated appear reasonable, but they could be computed more precisely by the same methods if more comprehensive data on the farm engine population becomes available.

C. Estimation of National Emissions Impact for Farm Engines

Calculation of total exhaust emissions (or "national impact") from farm tractors is relatively straightforward at this point, using the composite emissions factors from Table 39 and the tractor horsepower and hours usage from section V.A. Assuming that (flywheel hp/PTO hp) = 1.15 and that the tractor load factor is 0.57, a typical calculation would be

$$\frac{\text{ton}}{\text{yr}} \text{ Diesel Farm Tractor Exhaust HC - } 95.4 \times 10^6 \text{ PTO hp}$$
$$\times \frac{1.15 \text{ flywheel hp}}{1.00 \text{ PTO hp}} \times \frac{0.57 \text{ hp used}}{\text{flywheel hp}}$$
$$\times \frac{490 \text{ hr operation}}{\text{yr}} \times \frac{1.70 \text{ g HC}}{\text{hp hr}}$$
$$\times \frac{1.10 \times 10^{-6} \text{ ton}}{\text{g}} = 57.3 \times 10^3 \text{ ton/yr},$$

and this result is shown along with corresponding results for other tractor engine types and pollutants in Table 40. Crankcase (blowby) hydrocarbon emissions from gasoline engines were estimated at 20% of exhaust hydrocarbons according to the rationale developed in section III.D.

Total horsepower hours for the farm non-tractor applications were calculated using the assumptions in Table 33 and usage information later in section V.A. Engine power in Table 33 was assumed to be flywheel power, and the composite load factor of 0.52 was used uniformly to calculate emission loadings as given in Table 40. Evaporative emissions from gasoline-powered machines were computed by arriving at fuel tank volumes with enough capacity for about 8 hours' normal operation. These volumes and other information pertaining to evaporative emissions computation are summarized in Table 41. For the purposes of this report, the U.S. was divided into three regions (Northern, Central, and Southern), and the states included in each region are shown in Appendix H. The Northern region is approximately between 49° and 43° north latitude, the Central region between 43° and 37°, and the Southern region between 37° and 31°. Adoption of these arbitrary regions permitted computation of average days per year during which each machine was ready for use, by assuming the number of

TABLE 39. COMPUTATION OF COMPOSITE BRAKE SPECIFIC EMISSION FACTORS FOR FARM TRACTOR AND NON-TRACTOR APPLICATIONS OF HEAVY-DUTY DIESEL AND GASOLINE ENGINES

Engine Type and Application	Engine	*Assumed Fraction of Category hp hrs	Contribution to Composite Emission Factor, g/hp hr					
			HC	CO	NO_x	RCHO	SO_x	Particulate
Diesel Farm Tractor	Allis-Chalmers 3500	0.25	0.126	0.665	2.70	0.04	0.219	0.198
	Detroit Diesel 6V-71	0.05	0.031	0.074	1.16	0.006	0.045	0.010
	International Harv. D407	0.35	0.780	1.63	2.98	0.052	0.302	0.620
	John Deere 6404	0.25	0.732	0.665	1.46	0.22	0.228	0.305
	Perkins 4.236	0.10	0.039	0.322	1.07	0.019	0.080	0.142
$\sum$ = Category Composite Emission Factors =			1.71	3.36	9.37	0.34	0.874	1.28
Gasoline Farm Tractor	Ford G5000	0.90	4.82	116.	6.43	0.25	0.206	0.320
	J. I. Case 159G	**0.10	0.673	26.8	0.222	0.050	0.027	0.031
$\sum$ = Category Composite Emission Factors =			5.49	143.	6.62	0.30	0.233	0.351
Diesel Farm Non-Tractor	Allis-Chalmers 3500	0.15	0.082	0.478	1.62	0.024	0.136	0.135
	Caterpillar D6C	0.02	0.002	0.018	0.096	0.002	0.017	0.008
	Detroit Diesel 6V-71	0.05	0.035	0.091	1.18	0.006	0.046	0.010
	International Harv. D407	0.36	0.896	2.00	2.96	0.068	0.323	0.684
	John Deere 6404	0.15	0.482	0.447	0.831	0.13	0.142	0.201
	Mercedes-Benz DM636	0.02	0.021	0.075	0.057	0.005	0.022	0.040
	Onan DJBA	0.05	0.075	0.206	0.312	0.008	0.065	0.104
	Perkins 4.236	0.20	0.086	0.762	1.97	0.052	0.165	0.326
$\sum$ = Category Composite Emission Factors =			1.68	4.08	9.03	0.30	0.916	1.51
Gasoline Farm Non-Tractor	Ford G5000	0.30	1.77	43.2	2.06	0.090	0.071	0.098
	Hercules G2300	0.30	1.79	57.0	1.18	0.048	0.077	0.072
	J. I. Case 159G	**0.05	0.383	14.4	0.110	0.028	0.014	0.015
	Wisconsin VH4D	0.35	3.24	103.	1.89	0.049	0.119	0.180
$\sum$ = Category Composite Emission Factors =			7.18	218.	5.24	0.22	0.281	0.365

*assumptions are arbitrary and do not reflect actual market on population percentages - see discussion p. 61

**low weights given the Case engine's emissions because it was erroneously run with high restrictions - see discussion p. 26

TABLE 40. NATIONAL EMISSIONS IMPACT ESTIMATES FOR HEAVY-DUTY FARM ENGINES

Pollutant	Engine Application/Type	g/unit yr $x10^{-3}$	ton/yr $x10^{-3}$	Total for Pollutant ton/yr $x10^{-3}$
HC (Exhaust)	Tractor/Diesel	38.3	57.6	
	Tractor/Gasoline	37.3	128.	
	Non-Tractor/Diesel	3.2	3.0	
	Non-Tractor/Gasoline	9.0	12.2	201.
HC (Evaporative)	Tractor/Gasoline	15.6	52.7	
	Non-Tractor/Gasoline	2.1	2.9	55.6
HC (Crankcase)	Tractor/Gasoline	7.5	25.6	
	Non-Tractor/Gasoline	1.8	2.4	28.0
HC (Total)	Tractor/Diesel	38.3	57.6	
	Tractor/Gasoline	60.4	206.	
	Non-Tractor/Diesel	3.2	3.0	
	Non-Tractor/Gasoline	12.4	17.5	284.
CO	Tractor/Diesel	75.2	113.	
	Tractor/Gasoline	971.	3330.	
	Non-Tractor/Diesel	7.9	7.4	
	Non-Tractor/Gasoline	275.	369.	3820.
NO_x as NO_2	Tractor/Diesel	210.	316.	
	Tractor/Gasoline	45.2	155.	
	Non-Tractor/Diesel	17.4	16.3	
	Non-Tractor/Gasoline	6.6	8.9	496.
RCHO as HCHO	Tractor/Diesel	7.6	11.	
	Tractor/Gasoline	2.0	7.0	
	Non-Tractor/Diesel	0.6	0.5	
	Non-Tractor/Gasoline	0.3	0.4	19.
SO_x	Tractor/Diesel	19.6	29.5	
	Tractor/Gasoline	1.6	5.4	
	Non-Tractor/Diesel	1.8	1.7	
	Non-Tractor/Gasoline	0.4	0.5	37.1
Particulate	Tractor/Diesel	28.7	43.1	
	Tractor/Gasoline	2.4	8.2	
	Non-Tractor/Diesel	2.9	2.7	
	Non-Tractor/Gasoline	0.5	0.6	54.6

days available for outdoor (tractor) work in each region (180 days for the Northern region, 225 for the Central, and 270 for the Southern region).

The assumed days available for tractor work were weighted by the fractions of units in each region to arrive at the average tractor "usage" (days), and ratios of annual machine usage in hours were used to compute corresponding "days of usage" for the other applications. As an example, "days of usage" for self-propelled combines were calculated by

$$\text{days of usage (S-P combines)} = 229 \text{ days} \times$$

$$\times \frac{73 \text{ S-P combine hr/yr}}{291 \text{ gasoline tractor hr/hr}} = 57 \text{ days}$$

Note that this computation is used only to estimate the number of days per year during which fuel can evaporate from the tanks.

The evaporation factors in the last column of Table 41 were chosen on the basis of discussion in section III. D. The higher factor (for "unprotected" tanks) was deemed appropriate for tractors due to tank location and temperature extremes encountered, and it was assumed that half the engines in each other application had unprotected tanks (4.0 g HC/gallon tank volume day) and the other half had protected tanks (2.0 g HC/gallon tank volume day). A typical computation is evaporative hydrocarbons from gasoline farm tractors, which is performed

$$\text{(g/unit yr) gasoline farm tractor evap. HC} - 229 \frac{\text{day}}{\text{yr}} \times \frac{4.0 \text{ g HC}}{\text{gal vol day}} \times 17 \text{ gal}$$

$$= 15.6 \times 10^3 \text{ g/unit yr.}$$

TABLE 41. INFORMATION PERTINENT TO EVAPORATIVE EMISSIONS FROM HEAVY-DUTY GASOLINE FARM ENGINES

Application	Assumed Tank Vol, gal	Fraction of Units in Region: North	Central	South	Average Usage* days/yr	Evap. Factor, g/gal vol. day
Tractor	17	0.207	0.495	0.298	229	4.0
S-P Combine	40	0.245	0.576	0.179	56	3.0
Pull Combine	10	0.245	0.576	0.179	40	3.0
Baler	15	0.267	0.571	0.162	18	3.0
Miscellaneous	11	0.277	0.441	0.282	39	3.0

* Number of days on which engine is assumed to be in use or ready for use, and thus to have fuel in the tank.

To put emissions from farm machinery in perspective, Table 42 shows them compared to revised 1970 EPA Air Pollution Inventory data[27]. Note that this use of revised 1970 Inventory data is a departure from the practice followed in the previous final reports under the subject contract. The revised figures were not available for inclusion in the previous reports. In some cases, the estimated emissions from farm equipment make a small but significant contribution to the national totals from mobile sources, which is not unexpected due to the high usage and relatively large population of this equipment.

TABLE 42. COMPARISON OF HEAVY-DUTY FARM ENGINE EMISSIONS ESTIMATES WITH EPA NATIONWIDE AIR POLLUTANT INVENTORY DATA

	1970 EPA Inventory Data, 10^6 tons/yr[27] (Revised)		Heavy-Duty Farm Engine Estimates as % of	
Pollutant	All Sources	Mobile Sources	All Sources	Mobile Sources
Hydrocarbons	27.3	15.2	1.04	1.87
CO	100.7	78.1	3.79	4.89
NO_x	22.1	11.0	2.24	4.51
SO_x	33.4	1.0	0.11	3.7
Particulate	25.5	0.9	0.21	6.1

For farm machinery, the seasonal factors involved in usage are quite complex, so no attempt will be made to construct a seasonal emissions breakdown. A breakdown into urban and rural usage seems unnecessary, since most agriculture involving powered implements is performed in rural areas. A regional breakdown is possible, however, with the result that some 16% of emissions from heavy-duty farm engines appear to occur in the Northern region, 49% in the Central region, and 35% in the Southern region (states in each region shown in Appendix H). It should be noted, of course, that emissions from farm equipment do not generally occur in areas where air pollution problems are severe, so their impact should be considered in view of this factor.

In summary, the major assumptions made in computation of national emissions impact for farm equipment were:

1. The 1972 farm tractor population (4.469×10^6) and the populations of other major items of equipment (combines, balers, etc.) are correct as given in the literature. (see pp. 47, 48, 54, & 56)

2. Tractor usage in hr/yr can be approximated by $450 + 3.89\,(hp-50) - 5.45\,(A_i)$ for tractors of given horsepower and age. (see pp. 54 & 55)

3. Total operating time for equipment such as combines and balers can be estimated from total U. S. crop average. (see pp. 57 & 58)

4. The fraction of tractors of a given age A_i still surviving can be approximated by the function $F_i = S_i/N_i = e^{-0.00155A_i^2}$. (see pp. 49, 50 & 55)

5. Diesel and gasoline horsepower in the field can be approximated using the following considerations; (see pp. 49, 51-54)
   a. large tractors are predominantly diesel
   b. small tractors (considering entire population) are predominantly gasoline
   c. diesel market penetration is proportional to machine size and is increasing linearly with time.

6. Engine operating cycles can be estimated from manufacturers' operating data, and from consideration of the type of operation each type of engine undergoes in the field. (see pp. 58-60)

7. Emissions from heavy duty farm engines can be estimated by combining results of tests conducted under the subject program in a reasonable way. (see pp. 61-63)

VI. ESTIMATION OF EMISSION FACTORS AND NATIONAL IMPACT FOR HEAVY-DUTY ENGINES USED IN CONSTRUCTION APPLICATIONS

The construction applications of heavy-duty engines are treated in this section as a category separate from the farm and industrial applications. The reason for this approach is to utilize emissions data from the greatest number of engines in determining emission factors, while still separating the applications from one another along logical lines such as load factors and duty cycles.

A. Analysis of Population and Usage for Heavy-Duty Contruction Engines

Compared to the farm engine category, relatively few data are available on sales and population of construction equipment. The scarcity of information is partially due to the industry's general policy of not releasing production statistics, but also to the comparatively small amount of government record-keeping which is done on the construction industry. The major sources of data on construction equipment [19, 21, 28, 29, 30, 31] include useful generalizations on horsepower (total) in use, load factors and duty cycles for the larger machines, annual usage, and limited information on unit shipments by year. They do not include, however, any specific population data by machine type and manufacturer (or engine type), so estimates of this type (necessary to computation of emission factors and impact) will have to be made in lieu of factual information.

The usage of construction equipment is high and severe, as documented by several sources [19, 21, 30, 31, 32], so the useful life of the machines (in years) is correspondingly short. Since comprehensive population data are not available for construction equipment, estimates will have to be made based on what is known about useful life of the various equipment items (in total operating hours), their annual usage, and shipments of each type of machine over the years. The total number of operating hours which heavily-loaded machinery will endure appears to be 10,000 to 15,000 hours, with the failure point being defined as the number of hours at which maintenance expense and downtime become prohibitive. Depending on the type of operation required by a given owner, a machine may undergo high-load operation constantly until it is traded in, or its degree of usage may be tapered off as it ages to extend its life.

To determine life (in years) of each major equipment category, it will be assumed for the purpose of this report that track tractors and track loaders are good for 10,000 hours, and that all other categories of mobile construction equipment will last 12,000 hours. It is now necessary to estimate annual usage for the various types of machines so that life (in years) can be calculated.

Several sources of annual usage information are available (19, 21, 30, 32) and a synopsis of this information is provided in Figure 23. No clear consensus on usage as a function of power can be drawn, especially when the Caterpillar data are included, but the relationship shown on the graph (arrived at by trial and error),

$$\text{usage (hr/yr)} = 0.1\ (\text{hp})^{1.8} + 500,$$

provides a reasonable estimate for most of the smaller machines. The points for large scrapers and off-highway trucks (upper right portion of graph) are the only data available for these categories, so they will both be assigned a usage value of 2000 hr/yr on an arbitrary basis. The same usage will be assumed for wheel dozers. Note that 2080 hr/yr corresponds to working a 40-hour week all year long.

Data on the categories of mobile construction equipment necessary to computing average life (in years) are given in Table 43, along with the computed value itself (last column). This value for the life of each type of construction equipment should provide some idea of the number of years' shipments which are still in service, with corrections still to be made for exports.

TABLE 43. COMPUTATION OF AVERAGE YEARS OF SERVICE FOR SEVERAL CATEGORIES OF CONSTRUCTION EQUIPMENT

Category	Assumed Service Life, hr	Assumed Avg. hp	Annual Operation hr/yr	Computed Life, yr
Tracklaying Tractors	10,000	120	1050	9.5
Tracklaying Shovel Loaders	10,000	65	1100*	9.1
Motor Graders	12,000	90	830	14.5
Scrapers	12,000	475	2000	6.0
Off-Highway Trucks	12,000	400	2000	6.0
Wheel Loaders	12,000	130	1140	10.5
Wheel Tractors	12,000	75	740	16.2
Rollers	12,000	75	740	16.2
Wheel Dozers	12,000	300	2000	6.0

*compromise between data from references 12 & 30 and usage vs. hp model above.

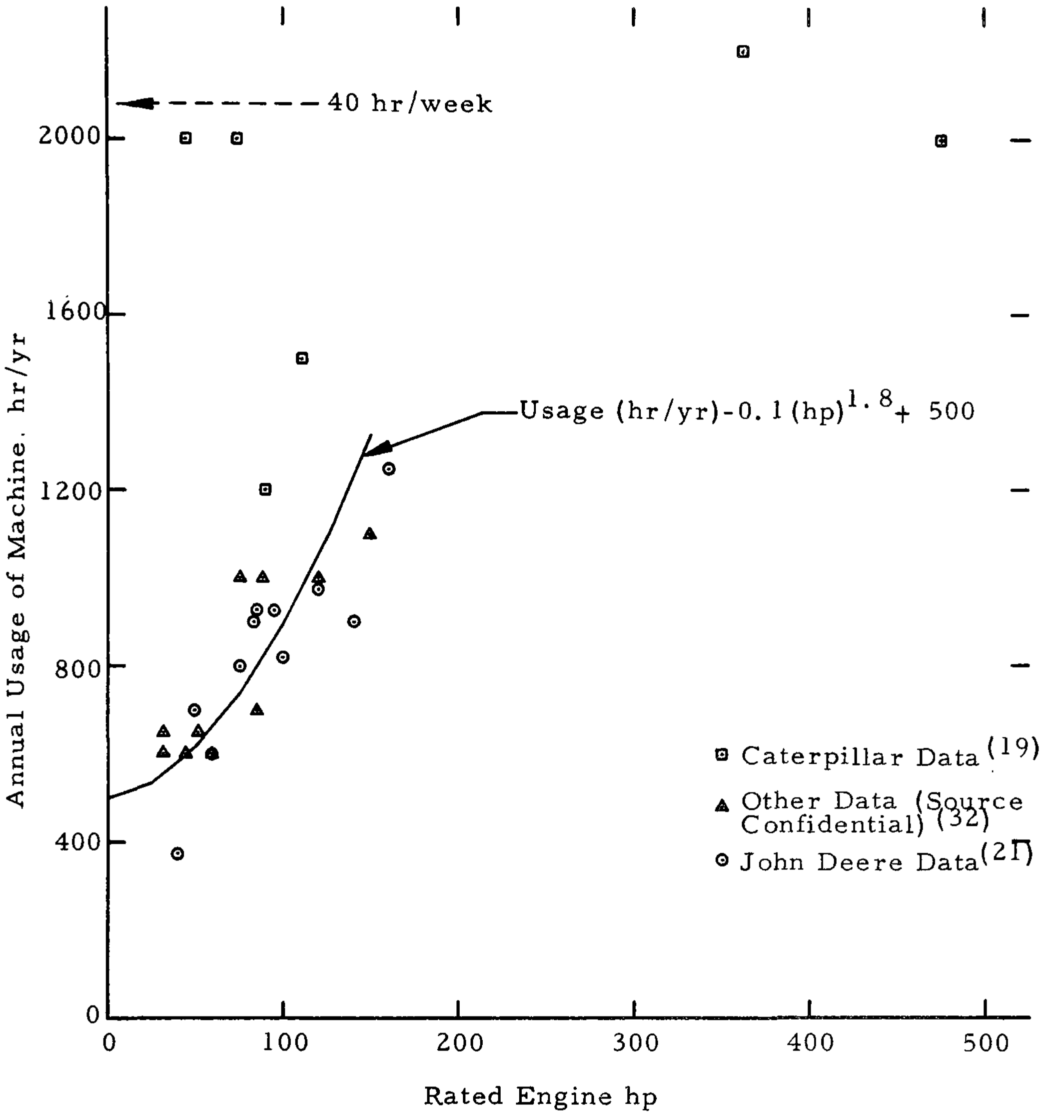

FIGURE 23. USAGE AS A FUNCTION OF RATED ENGINE HP FOR VARIOUS CATEGORIES OF CONSTRUCTION EQUIPMENT

Shipments of most types of construction machinery[28, 29] have not shown steady increases over the past 10 to 15 years, but rather they have shown variation about a more-or-less central or "typical" value. The generalization holds best for equipment items which are well-established and not undergoing major changes in sales, but this description applies well to almost all the categories of equipment. Based on this idea, a typical value has been arrived at for total yearly shipments of machines in each category over the period of its computed average life, and these values are given in Table 44. The table also gives estimates of domestic shipments (total shipments x 90%) over the computed average life for each category, which will be assumed for the purposes of this report to be the present population of machines in each category.

There are many other types of mobile and semi-mobile machines used in construction, including belt loaders, cranes, excavators, compressors, pumps, mixers, pavers, trenchers, vibratory compactors, and generators. Most of these machines are not broken out separately in available statistics, but a review of the machines currently available [33, 34] indicates that a typical unit may have an engine of 120 hp and a usage of perhaps 1000 hr/yr. It is estimated that at least 100,000 such machines are currently in use.

TABLE 44. TYPICAL TOTAL YEARLY SHIPMENTS AND DOMESTIC SHIPMENTS OVER COMPUTED AVERAGE LIFE FOR CONSTRUCTION EQUIPMENT

Category	Typical Total Annual Shipments	Domestic Shipments over Computed Average Life
Tracklaying Tractors	23,000	197,000
Tracklaying Shovel Loaders	10,500	86,000
Motor Graders	7,300	95,300
Scrapers	5,000	27,000
Off-Highway Trucks	3,850	20,800
Wheel Loaders	14,200	134,000
Wheel Tractors (incl. loader-backhoes)	30,000	437,000
Rollers	5,600	81,600
Wheel Dozers	500	2,700

B. Development of Emission Factors for Construction Engines

Emission factors for construction engines depend on the composition of the population by size and type of engine, as well as the duty cycle on which the engines are run. Addressing the latter topic first, a good deal of information is available on duty cycles for heavy machinery such as scrapers, tracklaying tractors, wheel loaders, and off-highway trucks [19, 21, 30, 31]. Information on duty cycles of rollers, wheel tractors, and motor graders, however, is very scarce. The available data on duty cycles are summarized in Table 45 in terms of weighting factors for the 13-mode cycle (see Table 2 for 13-mode cycle description if necessary). It should be noted that the composite load factors shown are not based on fuel usage, but that they are calculated by

$$\text{composite load factor} \quad \sum_{i=1}^{13} W_i F_i;$$

where

W_i - time-based mode weighting factor, and

F_i = fraction of maximum load at the speed for that mode.

This calculation gives a good approximation of a fuel-based load factor, whereas a similar calculation based on fraction of maximum (mode 8) horsepower will uniformly yield a factor which is lower than the fuel-based factor. In addition to the data in Table 45, composite load factors are given in the Caterpillar data [30] for wheel loaders (0.55), off-highway trucks (0.45), motor graders (0.50), and track loaders (0.65).

In assessing the validity of the data in Table 45, it should be noted that the Allis-Chalmers information (code B) was supplied not as shown, but as total factors at each power increment for both operating speeds. It is quite possible that the factor for, say, modes 6 and 8 for track tractors (supplied as 0.70) should have been split something other than 50-50, but no additional information was given to indicate what the split should be. Another point, first raised by Mr. John Crowley of the EMA-OAP Emissions Survey Subcommittee [23], is that the Allison data include very little time for warm up and idling, which would not necessarily be the case in practice.

The approach taken in order to develop logical duty cycles was to modify the Detroit Diesel-Allison data such that idles were weighted 0.15 for track tractors, scrapers, and off-highway trucks, and 0.10 for wheel loaders. The weighting factors for modes 2-6 and 8-12 were then multiplied by 0.85 ÷ (1.0-original idle weight) for the first three applications above or by 0.90 ÷ (1.0-original idle weight) for wheel loaders, so the sum of weighting factors in each case was still 1.0. The modified Allison data for track tractors and scrapers were then averaged with the Caterpillar data for track tractors and scrapers, respectively,

TABLE 45. SUMMARY OF MANUFACTURERS' CONSTRUCTION EQUIPMENT DUTY CYCLE DATA BASED ON 13-MODE CYCLE (see Table 2)

Mode(s)	Application	Factors by Source A	B	C[a]	Application	Factors by Source A	B	B[b]	C[c]
1, 7, 13	Tracklaying Tractor	0.15	0.03	0.006	Scraper	0.15	0.02	0.02	0.001
2		0.02	0	0.013		0.03	0.015	0.015	0.044
3		0.03	0	0.007		0.05	0	0	0.158
4		0.04	0.035	0.020		0.05	0.010	0.075	0.185
5		0.04	0.10	0.033		0.05	0.225	0.15	0.008
6		0.07	0.35	0.009		0.07	0.15	0.25	0.054
8		0.25	0.35	0.466		0.10	0.15	0.25	0.201
9		0.20	0.10	0.230		0.15	0.225	0.15	0.198
10		0.10	0.035	0.077		0.15	0.10	0.075	0.112
11		0.05	0	0.091		0.10	0	0	0.039
12		0.05	0	0.047		0.10	0.015	0.015	0
Composite Load Factor		0.59	0.88	0.75		0.46	0.74	0.80	0.60

Mode(s)	Application	Factors by Source B	C[d]	Application	Factors by Source B[e]	C
1, 7, 13	Wheel Loader	0.05	0.016	Off-Highway Truck	0.035	0.113
2		0.02	0.002		0.038	0.038
3		0.03	0.064		0.060	0.035
4		0.15	0.171		0.162	0.013
5		0.15	0		0.122	0.009
6		0.125	0		0.100	0.029
8		0.125	0.209		0.100	0.447
9		0.15	0.349		0.122	0.075
10		0.15	0.144		0.162	0.110
11		0.03	0.046		0.060	0.014
12		0.02	0		0.038	0.117
Composite Load Factor		0.64	0.66		0.58	0.62

Source A is Caterpillar[19, 30], Source B is Allis-Chalmers[31], Source C is Detroit Diesel-Allison[31]

[a] average of 9 usage cycles [b] self-loading scraper [c] elevating scraper
[d] average of 6 usage cycles [e] average of 2 truck types

to obtain the consensus factors for these two applications. Likewise, the Allison data for wheel loaders and off-highway trucks were averaged with corresponding Allis-Chalmers data to obtain consensus factors on these two latter applications.

The results of these procedures are given in Table 46, and it will be assumed that motor graders operate on the scraper cycle, that wheel tractors and wheel dozers operate on the track tractor cycle and that track loaders operate on the wheel loader cycle. For brevity, the track tractor cycle has been denoted C-1, the scraper cycle C-2, the wheel loader cycle C-3, and the off-highway truck cycle has been denoted C-4. In addition, it will be assumed that the "on-highway" 13-mode weighting factors apply to roller operation (0.20 for sum of idles, 0.08 for other modes), and that the weighting factors developed for farm non-tractor operation (semi-mobile) apply to the miscellaneous category of construction engines (Table 37). This latter cycle will henceforth be called "general purpose", with either "construction" or "industrial" added to denote the category of engines for which it is used in each instance. As stated in section V.B., the general-purpose factors were "...based on the ideas that most (of these) engines are governed at or near rated speed, and that they spend little time at idle," and these ideas hold equally well for miscellaneous construction engines. The consensus factors in Table 46 yield composite (calculated) load factors of about 0.61 for C-1, 0.49 for C-2, 0.62 for C-3, and 0.58 for C-4. The composite load factor for the 13-mode "on-highway" schedule is 0.40, and that for the general purpose construction schedule is about 0.52. Development of new composite cycles was considered an important secondary objective of the project, and the above discussion shows one of the ways in which this objective was met.

Computation of cycle composite mass emissions with mode weights as given in Table 46 followed the same procedure outlined in section V. These reweighted data are presented in Table 47, noting that the composite emissions based on the 13-mode "on-highway" factors appear in Tables 20, 21, and 23, and that those based on the general purpose construction schedule are given in Table 38 (under farm non-tractor heading). One outstanding feature of the data in Table 47 is the relatively small variation in composite specific emissions from one weighting schedule to another. This insensitivity of the specific emissions to the schedule reinforces the idea that errors in the weighting factors probably have a relatively weak effect on the overall emissions results.

To arrive at <u>category</u> composite emission factors for construction equipment, it is now necessary to assume a distribution for each category composed of test engines in some combination. These attempts are <u>not</u> estimates of the <u>actual</u> category compositions, but rather combinations which should produce reasonable category composite emission factors. The assumptions will be arbitrary, but they

TABLE 46. MODE WEIGHTING FACTORS FOR CHARACTERIZATION OF EMISSIONS FROM CONSTRUCTION EQUIPMENT

Procedure	Mode	Weighting Factor by Cycle[a] C-1	C-2	C-3	C-4
Particulate[b]	1	0.150	0.150	0.075	0.092
	2	0.028	0.102	0.044	0.069
	3	0.046	0.145	0.193	0.126
	4	0.061	0.069	0.109	0.106
	5	0.094	0.096	0.036	0.097
	6	0.171	0.195	0.225	0.194
	7	0.450	0.242	0.317	0.314
23-Mode[c]	1	0.050	0.050	0.025	0.031
	2	0.009	0.018	0.006	0.020
	3	0.009	0.034	0.015	0.023
	4	0.010	0.050	0.023	0.026
	5	0.013	0.053	0.052	0.037
	6	0.016	0.056	0.081	0.047
	7	0.017	0.036	0.060	0.042
	8	0.019	0.015	0.040	0.036
	9	0.020	0.023	0.036	0.035
	10	0.022	0.031	0.033	0.035
	11	0.050	0.050	0.025	0.031
	12	0.000	0.000	0.000	0.000
	13	0.186	0.074	0.085	0.153
	14	0.150	0.081	0.106	0.105
	15	0.114	0.087	0.126	0.056
	16	0.081	0.077	0.101	0.067
	17	0.048	0.067	0.076	0.078
	18	0.042	0.051	0.048	0.049
	19	0.037	0.036	0.019	0.021
	20	0.031	0.032	0.012	0.032
	21	0.026	0.027	0.005	0.044
	22	0.050	0.050	0.025	0.031
	23	0.000	0.000	0.000	0.000

Procedure	Mode	Weighting Factor by Cycle[a] C-1	C-2	C-3	C-4
13-Mode	1	0.050	0.050	0.025	0.031
	2	0.016	0.034	0.011	0.037
	3	0.018	0.092	0.044	0.047
	4	0.028	0.104	0.153	0.087
	5	0.034	0.028	0.075	0.066
	6	0.039	0.058	0.062	0.064
	7	0.050	0.050	0.025	0.031
	8	0.324	0.136	0.158	0.264
	9	0.198	0.159	0.234	0.097
	10	0.083	0.122	0.141	0.134
	11	0.064	0.066	0.036	0.036
	12	0.045	0.050	0.010	0.075
	13	0.050	0.050	0.025	0.031
21-Mode	1	0.050	0.050	0.025	0.031
	2	0.009	0.018	0.006	0.020
	3	0.009	0.034	0.015	0.023
	4	0.010	0.050	0.023	0.026
	5	0.013	0.053	0.052	0.037
	6	0.016	0.056	0.081	0.047
	7	0.017	0.036	0.060	0.042
	8	0.019	0.015	0.040	0.036
	9	0.020	0.023	0.036	0.035
	10	0.022	0.031	0.033	0.035
	11	0.050	0.050	0.025	0.031
	12	0.186	0.074	0.085	0.153
	13	0.150	0.081	0.106	0.105
	14	0.114	0.087	0.126	0.056
	15	0.081	0.077	0.101	0.067
	16	0.048	0.067	0.076	0.078
	17	0.042	0.051	0.048	0.049
	18	0.037	0.036	0.019	0.021
	19	0.031	0.032	0.012	0.032
	20	0.026	0.027	0.005	0.044
	21	0.050	0.050	0.025	0.031

(a) C-1 is for track and wheel tractors and wheel dozers
C-2 is for scrapers and motor graders
C-3 is for wheel loaders and track loaders
C-4 is for off-highway trucks

(b) sequence of conditions as shown in Table 22

(c) sequence of conditions as shown in Table 2

TABLE 47. COMPOSITE MASS AND BRAKE SPECIFIC EMISSIONS FOR TEST ENGINES WEIGHTED TO SIMULATE FOUR TYPES OF CONSTRUCTION USAGE

Engine	Weighting Schedule*	Mass Emissions in g/hr						Specific Emissions in g/hphr					
		HC	CO	NO_x	RCHO	SO_x	Part.	HC	CO	NO_x	RCHO	SO_x	Part.
Allis-Chalmers 3500	C-1	39.5	262.	908.	14.	73.4	66.1	0.465	3.09	10.7	0.15	0.864	0.732
	C-2	37.1	234.	730.	12.	58.7	60.1	0.563	3.55	11.1	0.17	0.890	0.886
	C-3	39.6	261.	900.	13.	71.0	72.7	0.483	3.19	11.0	0.15	0.866	0.817
	C-4	38.7	282.	856.	13.	68.5	70.5	0.492	3.59	10.9	0.16	0.871	0.862
Caterpillar D6-C	C-1	6.70	65.9	384.	6.6	71.8	34.9	0.078	0.767	4.46	0.074	0.835	0.383
	C-2	6.70	61.8	321.	6.4	58.0	27.9	0.099	0.916	4.75	0.092	0.860	0.404
	C-3	6.22	53.9	395.	6.5	73.1	31.9	0.073	0.635	4.65	0.074	0.861	0.351
	C-4	6.75	64.9	365.	6.6	67.4	30.9	0.084	0.806	4.55	0.079	0.839	0.371
Detroit Diesel 6V-71	C-1	68.3	276.	2650.	12.	106.	21.6	0.578	2.33	22.4	0.094	0.895	0.172
	C-2	60.9	211.	2130.	12.	85.2	18.8	0.661	2.29	23.1	0.12	0.924	0.199
	C-3	65.5	227.	2620.	12.	102.	21.6	0.565	1.96	22.6	0.099	0.884	0.174
	C-4	66.9	284.	2450.	12.	99.4	20.4	0.608	2.58	22.2	0.11	0.904	0.141
International Harvester D407	C-1	137.	375.	568.	8.1	54.1	115.	2.16	5.90	8.95	0.12	0.852	1.72
	C-2	121.	294.	418.	8.3	44.0	96.8	2.42	5.88	8.36	0.16	0.880	1.91
	C-3	130.	338.	519.	8.2	52.9	115.	2.07	5.38	8.25	0.13	0.841	1.72
John Deere 6404	C-1	210.	220.	521.	61.	69.6	97.0	2.68	2.81	6.67	0.75	0.890	1.16
	C-2	195.	201.	350.	56.	55.8	87.0	3.24	3.35	5.83	0.91	0.928	1.40
	C-3	210.	209.	434.	61.	66.7	105.	2.79	2.78	5.75	0.78	0.885	1.29
	C-4	210.	233.	447.	58.	64.5	102.	2.92	3.24	6.21	0.78	0.897	1.36
Perkins 4.236	C-1	14.1	222.	461.	7.9	34.4	59.5	0.330	5.19	10.8	0.18	0.806	1.33
	C-2	15.7	139.	338.	7.5	26.6	46.1	0.483	4.29	10.4	0.22	0.818	1.39
	C-3	14.7	153.	433.	7.5	32.1	52.6	0.361	3.75	10.6	0.18	0.789	1.32
Ford G5000 (G256)	C-1	212.	4530.	313.	11.	8.81	17.6	5.26	112.	7.75	0.26	0.218	0.413
	C-2	185.	4250.	213.	9.3	7.30	12.6	6.00	138.	6.91	0.29	0.237	0.397
	C-3	199	4810.	268.	11.	8.60	15.6	5.15	125.	6.94	0.27	0.223	0.376
Hercules G-2300	C-1	220.	6980.	208.	6.9	10.0	11.1	5.17	164.	4.89	0.16	0.235	0.247
	C-2	197.	6060.	138.	5.1	8.30	8.29	6.07	186.	4.23	0.15	0.255	0.249
	C-3	225.	7130.	174.	6.2	9.79	10.0	5.52	175.	4.27	0.15	0.240	0.230
J. I. Case 159G	C-1	148.	5930.	58.4	12.	6.16	9.59	6.30	253.	2.48	0.50	0.262	0.387
	C-2	136.	5200.	41.1	10.	5.21	6.40	7.46	286.	2.26	0.56	0.286	0.344
	C-3	148.	5910.	50.3	12.	6.03	8.28	6.45	258.	2.20	0.50	0.263	0.339
Wisconsin VH4D	C-3	133.	4270.	101.	2.2	5.17	8.56	7.81	251.	5.91	0.12	0.304	0.470

*C-1 applies to track tractors, wheel tractors, and wheel dozers
C-2 applies to scrapers and motor graders
C-3 applies to track loaders and wheel loaders
C-4 applies to off-highway trucks

are also necessary because the distribution of engines in service is simply not known. With these qualifications, the assumptions made for the purposes of this report are given in Table 48, along with the assumed contribution of each engine to the category composite factors and the composite factors themselves. These factors appear reasonable, but confidence in them could certainly be strengthened if more data were available on engines operating in the field.

C. Estimation of National Emissions Impact for Construction Engines

Proceeding along a course parallel to that used on farm equipment in section V, impact estimates have been calculated for the various categories of construction equipment, and they appear in Table 49. The numbers on which the estimates are based were taken from Tables 43, 44, and 48, and a sample calculation for hydrocarbons from track-laying tractors is

$$\text{(ton/yr)track tractor HC} = 197{,}000 \text{ units} \times \frac{20 \text{ hp}}{\text{unit}} \times 0.61$$

$$\times 1050 \text{ hr/yr} \times 0.685 \frac{\text{g HC}}{\text{hp hr}} \times \frac{1.10 \times 10^{-6} \text{ ton}}{\text{g}} = 11{,}400 \text{ ton/yr.}$$

It was assumed that diesel engines produce negligible crankcase vent losses, and that all the gasoline engines used in construction have uncontrolled crankcase vents. It was also assumed that evaporation of diesel fuel is negligible, that gasoline evaporated from unprotected tanks (wheel tractors, motor graders, and half the tanks used on rollers and miscellaneous engines) at the rate of 4g/(gallon tank volume day); and that gasoline evaporated from protected tanks (half of those used on rollers and miscellaneous engines) at the rate of 2g/(gallon tank volume day).

The average length of the construction season (in days) was computed by assuming a 7-month season in the Northern region (down to 43° north latitude), an 8-month season in the Central region (43° to 37°), and a 9-month season in the Southern Region (37° and further south). These seasons were weighted by the distribution of contractors' work (excluding homebuilding)(35) as of October 1972, which was 9.2% in the Northern region, 51.7% in the Central region, and 39.1% in the Southern region. The result was a weighted mean season of 249 days, which is the period over which the evaporative emissions were assumed to occur. The fuel tanks on the gasoline-powered equipment were assumed to be adequate for 8 hours of normal operation, and their volumes were then calculated using fuel consumption figures for the test engines.

To place emissions from construction equipment in perspective, Table 50 shows them compared to revised 1970 EPA Air Pollution

TABLE 48. COMPUTATION OF CATEGORY COMPOSITE BRAKE SPECIFIC EMISSION FACTORS FOR HEAVY-DUTY ENGINES USED IN CONSTRUCTION APPLICATIONS

Application	Engine	*Assumed Fraction of Category hp hrs	Contribution to Category Emission Factor, g/hp hr HC	CO	NO_x	RCHO	SO_x	Part.
Tracklaying Tractor (C-1)	Allis-Chalmers 3500	0.10	0.046	0.309	1.07	0.015	0.086	0.073
	Caterpillar D6C	0.45	0.035	0.345	2.01	0.033	0.376	0.172
	Detroit Diesel 6V-71	0.15	0.087	0.350	3.36	0.014	0.134	0.026
	International Har. D407	0.10	0.216	0.590	0.895	0.012	0.085	0.172
	John Deere 6404	0.10	0.268	0.281	0.667	0.075	0.089	0.116
	Perkins 4.236	0.10	0.033	0.519	1.08	0.018	0.081	0.133
∑=Category Composite Emission Factors =			0.685	2.39	9.08	0.17	0.851	0.692
Wheel Tractor (C-1)	Allis-Chalmers 3500	0.20	0.093	0.618	2.14	0.030	0.173	0.146
	International Har. D407	0.25	0.540	1.48	2.24	0.030	0.213	0.430
	John Deere 6404	0.20	0.536	0.562	1.33	0.15	0.178	0.232
	Perkins 4.236	0.25	0.082	1.30	2.70	0.045	0.202	0.332
	Ford G5000 (G256)	0.06	0.316	6.72	0.465	0.016	0.013	0.025
	Hercules G-2300	0.03	0.155	4.92	0.147	0.005	0.007	0.007
	J. I. Case 159G	**0.01	0.063	2.53	0.025	0.005	0.003	0.004
∑=Category Composite Emission Factors =			1.78	18.1	9.05	0.28	0.789	1.18
Wheel Dozer (C-1)	Allis-Chalmers 3500	0.10	0.046	0.309	1.07	0.015	0.086	0.073
	Caterpillar D6C	0.40	0.031	0.307	1.78	0.030	0.334	0.153
	Detroit Diesel 6V-71	0.40	0.231	0.932	8.96	0.038	0.358	0.069
	John Deere 6404	0.10	0.268	0.281	0.667	0.075	0.089	0.116
∑=Category Composite Emission Factors =			0.576	1.83	12.5	0.16	0.867	0.411
Scraper (C-2)	Allis-Chalmers 3500	0.20	0.113	0.710	2.22	0.034	0.178	0.177
	Caterpillar D6C	0.20	0.020	0.183	0.950	0.018	0.172	0.081
	Detroit Diesel 6V-71	0.30	0.198	0.687	6.93	0.036	0.277	0.060
	International Har. D407	0.10	0.242	0.588	0.836	0.016	0.088	0.191
	John Deere 6404	0.20	0.648	0.670	1.17	0.18	0.186	0.280
∑=Category Composite Emission Factors			1.22	2.84	12.1	0.28	0.901	0.789
Motor Grader (C-2)	Caterpillar D6C	0.50	0.050	0.458	2.38	0.046	0.430	0.202
	Detroit Diesel 6V-71	0.25	0.165	0.572	5.78	0.030	0.231	0.050
	International Har. D407	0.10	0.242	0.588	0.836	0.016	0.088	0.191
	Perkins 4.236	0.10	0.048	0.429	1.04	0.022	0.082	0.139
	Ford G5000 (G256)	0.02	0.120	2.76	0.138	0.006	0.005	0.008
	Hercules G-2300	0.02	0.121	3.72	0.085	0.003	0.005	0.005
	J. I. Case 159G	**0.01	0.075	2.86	0.023	0.006	0.003	0.003
∑=Category Composite Emission Factors			0.821	11.4	10.3	0.13	0.844	0.598
Wheel Loader (C-3)	Allis-Chalmers 3500	0.10	0.048	0.319	1.10	0.015	0.087	0.082
	Caterpillar D6C	0.20	0.015	0.127	0.930	0.015	0.172	0.070
	Detroit Diesel 6V-71	0.20	0.113	0.392	4.52	0.020	0.177	0.035
	International Har. D407	0.12	0.298	0.646	0.990	0.016	0.101	0.206
	John Deere 6404	0.10	0.279	0.278	0.575	0.078	0.088	0.129
	Perkins 4.236	0.12	0.043	0.450	1.27	0.022	0.095	0.158
	Ford G5000 (G256)	0.07	0.360	8.75	0.486	0.019	0.016	0.026
	Hercules G-2300	0.07	0.386	12.2	0.299	0.010	0.017	0.016
	J. I. Case 159G*	0.01	0.064	2.58	0.022	0.005	0.003	0.003
	Wisconsin VH4D	0.01	0.078	2.51	0.059	0.001	0.003	0.005
∑=Category Composite Emission Factors			1.63	28.3	10.3	0.20	0.759	0.730

Continued on next page.

*assumptions are arbitrary and do not reflect actual market or population percentages - see discussion p. 74

**low weights given the Case engine's emissions because it was erroneously run with high restrictions - see discussion p. 26

TABLE 48. (Cont'd.) COMPUTATION OF CATEGORY COMPOSITE BRAKE SPECIFIC EMISSION FACTORS FOR HEAVY-DUTY ENGINES USED IN CONSTRUCTION APPLICATIONS

Application	Engine	*Assumed Fraction of Category hp hrs	Contribution to Category Emission Factor, g/hp hr HC	CO	NO_x	RCHO	SO_x	Part.
Tracklaying Loader (C-3)	Allis-Chalmers 3500	0.15	0.072	0.478	1.65	0.022	0.130	0.123
	Caterpillar D6C	0.65	0.047	0.413	3.02	0.048	0.560	0.228
	International Har. D407	0.10	0.207	0.538	0.825	0.013	0.084	0.172
	Perkins 4.236	0.10	0.036	0.375	1.06	0.018	0.079	0.132
Σ=Category Composite Emission Factors =			0.362	1.80	6.56	0.10	0.853	0.655
Off-Highway Truck (C-4)	Allis-Chalmers 3500	0.20	0.098	0.718	2.18	0.032	0.174	0.172
	Caterpillar D6C	0.15	0.013	0.121	0.682	0.012	0.126	0.056
	Detroit Diesel 6V-71	0.50	0.304	1.29	11.1	0.055	0.452	0.070
	John Deere 6404	0.15	0.438	0.486	0.932	0.12	0.135	0.204
Σ=Category Composite Emission Factors =			0.853	2.62	14.9	0.22	0.887	0.502
Roller (13-Mode On-Highway)	Detroit Diesel 6V-71	0.20	0.140	0.592	4.04	0.030	0.192	0.042
	Mercedes-Benz OM636	0.05	0.060	0.253	0.166	0.015	0.066	0.111
	Perkins 4.236	0.05	0.033	0.248	0.535	0.014	0.042	0.077
	Ford G5000 (G256)	0.30	2.66	47.7	2.01	0.10	0.078	0.132
	Hercules G-2300	0.30	2.69	63.0	1.22	0.051	0.083	0.087
	J. I. Case 159G	**0.02	0.268	6.32	0.176	0.013	0.006	0.008
	Wisconsin VH4D	0.08	0.857	24.7	0.422	0.012	0.028	0.049
Σ=Category Composite Emission Factors =			6.71	193.	8.57	0.24	0.495	0.506
Miscellaneous (General Purpose Const.)	Allis-Chalmers 3500	0.05	0.028	0.159	0.540	0.008	0.045	0.045
	Caterpillar D6C	0.05	0.005	0.045	0.239	0.004	0.043	0.020
	Detroit Diesel 6V-71	0.40	0.282	0.724	9.40	0.048	0.372	0.083
	International Har. D407	0.10	0.249	0.556	0.822	0.019	0.090	0.190
	John Deere 6404	0.05	0.160	0.149	0.277	0.043	0.047	0.067
	Mercedes-Benz OM636	0.08	0.082	0.301	0.228	0.021	0.088	0.161
	Onan DJBA	0.02	0.030	0.083	0.125	0.003	0.026	0.042
	Perkins 4.236	0.10	0.043	0.381	0.983	0.026	0.082	0.163
	Ford G5000 (G256)	0.04	0.236	5.76	0.274	0.012	0.010	0.013
	Hercules G-2300	0.08	0.477	15.2	0.314	0.013	0.021	0.019
	J. I. Case 159G	**0.01	0.077	2.87	0.022	0.006	0.003	0.003
	Wisconsin VH4D	0.02	0.185	5.86	0.108	0.003	0.007	0.010
Σ=Category Composite Emission Factors =			1.85	32.1	13.3	0.21	0.834	0.816

*assumptions are arbitrary and do not reflect actual market or population percentages see discussion p. 74

**low weights given the Case engine's emissions because it was erroneously run with high restrictions - see discussion p. 26

TABLE 49. NATIONAL EMISSIONS IMPACT ESTIMATES FOR HEAVY-DUTY CONSTRUCTION ENGINES

Pollutant	Engine Application	$(g/unit\ yr) \times 10^{-3}$ Gasoline	$(g/unit\ yr) \times 10^{-3}$ Diesel	ton/yr $\times 10^{-3}$	Total for Pollutant, ton/yr $\times 10^{-3}$
HC (Exhaust)	Tracklaying Tractor	-	52.6	11.4	
	Wheel Tractor	121.	49.7	29.0	
	Wheel Dozer	-	211.	0.3	
	Scraper	-	568.	16.9	
	Motor Grader	154.	20.5	3.2	
	Wheel Loader	275.	96.6	22.1	
	Tracklaying Loader	-	16.0	1.0	
	Off-Highway Truck	-	396.	4.5	
	Roller	205.	18.3	13.4	
	Miscellaneous	254.	71.4	12.7	114.
HC (Evaporative)	Wheel Tractor	22.9	-	1.7	
	Motor Grader	24.9	-	0.2	
	Wheel Loader	33.9	-	1.5	
	Roller	20.9		1.3	
	Miscellaneous	25.4	-	0.7	5.4
HC (Crankcase)	Wheel Tractor	24.1	-	1.7	
	Motor Grader	30.8		0.2	
	Wheel Loader	54.9	-	2.4	
	Roller	41.1	-	2.6	
	Miscellaneous	50.7	-	1.3	8.2
HC (Total)	Tracklaying Tractor	-	52.6	11.4	
	Wheel Tractor	168.	49.7	32.4	
	Wheel Dozer	-	211.	0.3	
	Scraper	-	568.	16.9	
	Motor Grader	210.	20.5	3.6	
	Wheel Loader	364.	96.6	26.0	
	Tracklaying Loader	-	16.0	1.0	
	Off-Highway Truck	-	396.	4.5	
	Roller	267.	18.3	17.3	
	Miscellaneous	330.	71.4	14.7	128.
CO	Tracklaying Tractor	-	184.	39.9	
	Wheel Tractor	3200.	720.	295.	
	Wheel Dozer		670.	0.8	
	Scraper	-	1320.	39.2	
	Motor Grader	4560.	81.1	43.8	
	Wheel Loader	8050.	286.	383.	
	Tracklaying Loader	-	79.8	4.9	
	Off-Highway Truck	-	1220.	14.0	
	Roller	4500.	61.8	285.	
	Miscellaneous	7720.	188.	220.	1330.

Continued on next page.

TABLE 49. (Cont'd.) NATIONAL EMISSIONS IMPACT ESTIMATES FOR HEAVY-DUTY CONSTRUCTION ENGINES

Pollutant	Engine Application	(g/unit yr) x 10^{-3} Gasoline	Diesel	ton/yr x 10^{-3}	Total for Pollutant, ton/yr x 10^{-3}
NO_x as NO_2	Tracklaying Tractor	-	698.	151.	
	Wheel Tractor	144.	334.	147.	
	Wheel Dozer	-	4580.	5.6	
	Scraper	-	5630.	167.	
	Motor Grader	120.	397.	39.5	
	Wheel Loader	268.	1240.	140.	
	Tracklaying Loader	-	291.	18.0	
	Off-Highway Truck	-	6910.	79.4	
	Roller	121.	351.	17.1	
	Miscellaneous	187.	1030.	91.3	856.
RCHO as HCHO	Tracklaying Tractor	-	13.	2.8	
	Wheel Tractor	5.9	10.	4.6	
	Wheel Dozer	-	59.	0.1	
	Scraper	-	130.	3.9	
	Motor Grader	7.3	4.6	0.5	
	Wheel Loader	11.	21.4	2.7	
	Tracklaying Loader		4.4	0.3	
	Off-Highway Truck	-	102.	1.2	
	Roller	5.6	5.5	0.5	
	Miscellaneous	9.0	13.9	1.4	18.
SO_x as SO_2	Tracklaying Tractor	-	65.4	14.2	
	Wheel Tractor	5.2	30.3	12.8	
	Wheel Dozer	-	317.	0.4	
	Scraper	-	419.	12.4	
	Motor Grader	6.3	32.4	3.2	
	Wheel Loader	12.1	94.1	10.3	
	Tracklaying Loader	-	37.8	2.3	
	Off-Highway Truck	-	412.	4.7	
	Roller	6.2	22.6	1.0	
	Miscellaneous	10.6	64.7	5.7	67.0
Particulate	Tracklaying Tractor	-	53.2	11.5	
	Wheel Tractor	8.1	45.5	19.2	
	Wheel Dozer		150.	0.2	
	Scraper	-	367.	10.9	
	Motor Grader	7.8	23.0	2.3	
	Wheel Loader	15.4	88.8	9.9	
	Tracklaying Loader	-	29.0	1.8	
	Off-Highway Truck	-	233.	2.7	
	Roller	8.7	16.8	1.0	
	Miscellaneous	11.7	63.2	5.6	65.1

TABLE 50. COMPARISON OF HEAVY-DUTY CONSTRUCTION ENGINE EMISSIONS ESTIMATES WITH EPA NATIONWIDE AIR POLLUTANT INVENTORY DATA

Pollutant	1970 EPA Inventory Data, 10^6 tons/yr[27] (Revised) All Sources	Mobile Sources	Heavy-Duty Construction Engine Estimates as % of All Sources	Mobile Sources
Hydrocarbons	27.3	15.2	0.469	0.842
CO	100.7	78.1	1.32	1.70
NO_x	22.1	11.0	3.87	7.78
SO_x	33.4	1.0	0.20	6.7
Particulate	25.5	0.9	0.26	7.2

Inventory data [27]. Construction engines appear to make relatively small contributions to total hydrocarbons and CO, but more significant contributions to totals of the other emissions. The emissions impact values presented here differ sharply, in some cases, with previously-published values for construction equipment, and the reason for the differences is primarily the inclusion of some gasoline-powered machinery in the subject estimates. The influence of the gasoline engines is illustrated by Table 51, which compares the results of a previous study [30] with those of the subject work. While the agreement between the earthmoving machinery contribution from this study and the total of the previous work is not perfect, it shows few basic disagreements. If SO_x were calculated for the previous study by the same method used for this report, for instance, the resulting figure would be about 62,800 tons rather than the 107,000 tons shown. On the particulate values, it can only be said that the emission factors used were substantially different.

TABLE 51. COMPARISON OF EMISSION ESTIMATES FOR GASOLINE- AND DIESEL-POWERED EQUIPMENT WITH A PREVIOUS EMISSION ESTIMATE

Coverage of Estimate/Source	Estimated Ton/yr x10^{-3} HC	CO	NO_x	SO_x	Particulate
All Const. Equpt./this report	128.	1330.	856.	67.0	65.0
Gasoline Const. Equpt./this report	55.2	1110.	35.6	1.6	2.2
Diesel Const. Equpt./this report	72.8	220.	820.	65.4	62.8
Earth moving Equpt.*/this report	63.3	176.	583.	46.6	38.4
Earthmoving Equpt.*/[30]	44.0	223.	625.	107.	20.0

*does not include any gasoline-powered equipment or any rollers, wheel dozers, wheel tractors (except scraper tractors), or miscellaneous engines

Some of the information required to summarize emissions from construction equipment on a seasonal/regional basis has already been developed, namely the assumed operating seasons and fractions of the engine population in the three regions. No data are available, however, on the distribution of construction activity between urban/suburban and rural areas, so it will be estimated that 75% of the activity is in urban/suburban areas. These simplistic assumptions permit the compiling of Table 52, which gives valuable results even though it is necessarily quite heavily qualified. The analysis estimates that some 20% of emissions from construction equipment occur in the winter months, about 30% in the summer months, and that spring and fall each account for about 25%. It also estimates that about 8% of emissions from construction equipment occur in the Northern region, 50% in the Central region, and 42% in the Southern region. (states included in regions shown in Appendix H).

TABLE 52. ESTIMATE OF SEASONAL, REGIONAL, AND URBAN-RURAL DISTRIBUTION OF EMISSIONS FROM CONSTRUCTION EQUIPMENT

	Percentage of Annual Nationwide Emissions by Season								
	Urban/Suburban Areas				Rural Areas				
Region	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Subtotals
Northern	0.83	1.46	2.09	1.46	0.28	0.49	0.70	0.49	7.80
Central	7.01	9.34	11.68	9.34	2.34	3.11	3.89	3.11	49.82
Southern	7.06	7.95	8.83	7.95	2.35	2.65	2.94	2.65	42.38
Subtotals	14.90	18.75	22.60	18.75	4.97	6.25	7.53	6.25	
Totals	75.00				25.00				100.00

In summary, the major assumptions made in computation of national emissions impact for construction equipment were:

1. The service life of construction machinery is 10,000 to 12,000 hours, as shown in the tabulation at the end of this summary; and the average horsepower of machines in several categories is as shown in the same tabulation (see pp. 68 & 69)

2. Annual operating time for construction machines can be approximated by

$$\text{usage (hr/yr)} = 500 + 0.1\,(\text{hp})^{1.8};$$

except for tracklaying shovel loaders, off-highway trucks, and scrapers, for which other data are available. (see pp. 69 & 70)

3. The life of construction equipment (in years) computed from service life (in hours) and usage (in hours/year), can be used with typical annual shipments to estimate number of units in service, as shown in the tabulation on the next page. (see pp. 69 & 71)

4. Emissions from heavy duty construction engines can be estimated by combining results of tests conducted under the subject program in a reasonable way. (see pp. 78 & 79)

5. Engine operating cycles can be estimated from manufacturers' operating data. (see pp. 71-77)

TABULATION OF PERTINENT ASSUMPTIONS AND COMPUTED VALUES

Category	Assumed Service Life, hr	Assumed Avg. hp	Annual Operation, hr/yr	Computed Life, yr	Typical Total Annual Shipments	*Domestic Shipments Over Computed Average Life
Track Tractors	10,000	120	1050	9.5	23,000	197,000
Track Shovel Loaders	10,000	65	1100	9.1	10,500	86,000
Motor Graders	12,000	90	830	14.5	7,300	95,300
Scrapers	12,000	475	2000	6.0	5,000	27,000
Off-Hwy. Trucks	12,000	400	2000	6.0	3,850	20,800
Wheel Loaders	12,000	130	1140	10.5	14,200	134,000
Wheel Tractors	12,000	75	740	16.2	30,000	437,000
Rollers	12,000	75	740	16.2	5,600	81,600
Wheel Dozers	12,000	300	2000	6.0	500	2,700
General Purpose	-	120	1000	-	-	100,000

*including assumption of 10% exports

VII. ESTIMATION OF EMISSION FACTORS AND NATIONAL IMPACT FOR HEAVY-DUTY ENGINES USED IN INDUSTRIAL APPLICATIONS

This section treats industrial engines as a category separate from farm and construction engines for purposes of estimating emission factors and national emissions impact. This approach permits utilization of emission data from the largest number of engines in determining emission factors, while still retaining separation between the application categories. Some of the engine applications included in the industrial classification are: fork lifts; mobile refrigeration units; auxillary engines for hydraulic pump service on garbage trucks and other large vehicles; generator and pump service for utilities, airports, and state maintenance organizations; logging; mining; quarrying; oil field operations; and portable well-drilling equipment.

A. Analysis of Population and Usage for Heavy-Duty Industrial Engines

Of the three application categories for heavy-duty engines which are discussed in this report, the industrial category is the most difficult to define. The attempt made here is to include the engine applications named above while excluding applications such as agriculture, construction, railway motive power, marine propulsion, miscellaneous small engine applications, and others covered by separate reports under the subject contract. The greatest difficulties occur in separating engines classified as "miscellaneous 4-stroke small utility engines"(36) and engines designed for railway motive power from available production and shipment statistics(37).

As averages over the past 10 years, shipments of industrial gasoline engines have averaged about 1.1 million, and industrial diesel engine shipments have averaged about 50,000. No data are available on the size distribution of this particular group of engines, but data are given regarding the value of the engines at the manufacturer's plant. For the years 1969-1970, the average value of gasoline engines was about $120, and that for diesel engines was about $1900 (excluding engines for railway motive power). In order to interpret these values in terms of engine horsepower, other tables in the Bureau of the Census data(37) were consulted, with the results shown in Figure 24. These data indicate that the average horsepower of gasoline engines shipped was about 10, and that the average horsepower of diesel engines shipped was about 125.

Considering the detail with which applications of diesel engines (other than industrial) have been dealt under the subject contract, the value of 50,000 engine shipments per year can probably be assumed

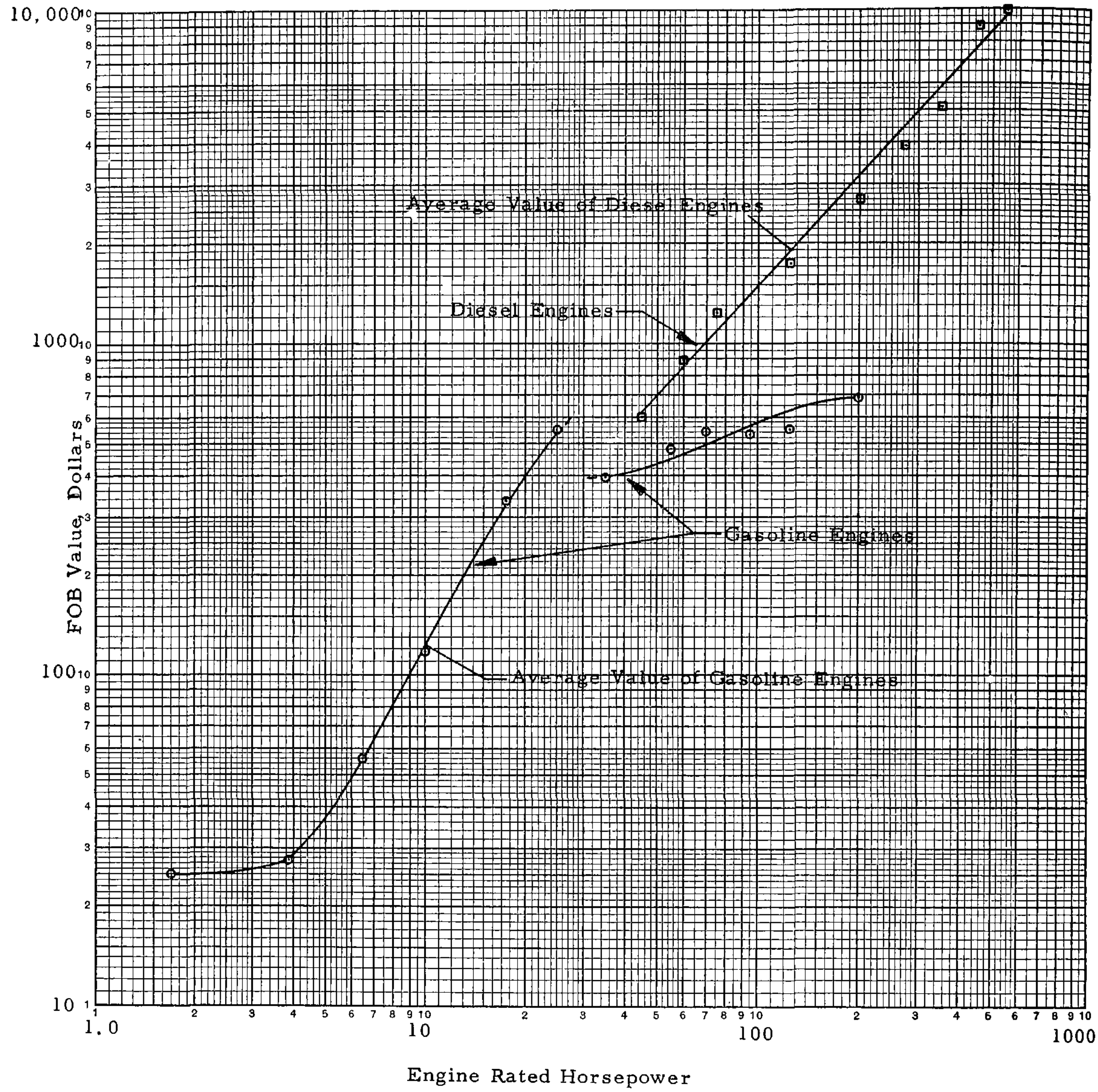

FIGURE 24. VALUE OF INDUSTRIAL ENGINES AS A FUNCTION OF ENGINE RATED HORSEPOWER (37)

to exclude most of the unwanted applications. For gasoline engines, however, the average horsepower estimate of 10 indicates that a large number of engines already treated in the Part 4 Final Report (36) on small general utility engines are showing up in the industrial gasoline engine shipment figures. These engines made their appearance under the "miscellaneous 4-stroke" category in that report, and the current population of the category was estimated at 6.38 million. The category was assumed to include industrial applications of small utility engines, so duplication must be avoided here.

The average rated horsepower of engines in the "miscellaneous 4-stroke" category (36) was assumed to be 3.86 hp, so if the fraction of gasoline engines classified "industrial" in the statistics (37) which are actually in the small engine category were known, a new average horsepower and unit value could be computed. The fraction of shipments currently double-classified is not known, but an increasing series of fractions can be assumed, and the subsequent calculations should show what fraction is reasonable. This computation is outlined in Table 53, and it is apparent that a substantial number of engines classified industrial are actually in the small engine group, judging by the computed average horsepower values.

Estimation of a reasonable average horsepower for gasoline industrial engines is not straightforward, but a look through listings of engines available over the past years (28) indicates a horsepower range from under 20 hp to over 250 hp for non-automotive engines. Considering that the industrial rating of most engines is very conservative, that is, it may be only around half the maximum (intermittent) rating, 55 hp (continuous rating) seems like a reasonable average. This engine might have a maximum (intermittent) rating of 75 to 80 hp, but it will be considered as rated on a continuous basis for this report. The result of this computation, then, is that an estimated 132,000 industrial gasoline engines are shipped each year, with the remainder of those classified "industrial" in the Bureau of the Census data (37) assumed included with other small engines in an earlier report (36) (that is, 88% of the gasoline engines classified "industrial" will be assumed to be small utility engines).

Usage of industrial engines is another unknown, but for the purposes of this report it will be assumed as approximately one-half that predicted for comparably-sized construction engines by the relationship shown in Figure 23. These values would be 600 hours for diesels and 300 hours for gasoline engines. Useful service life for industrial engines probably depends to a large extent on type of operation, but since no positive information is available, the values of 5000 hr for diesel engines and 2500 hr for gasoline engines will be used. These figures result in population estimates of 417.000 for

TABLE 53. COMPUTATION OF INDUSTRIAL GASOLINE ENGINE AVERAGE HORSEPOWER BASED ON ASSUMPTIONS ABOUT DOUBLE-CLASSIFICATION OF SMALL UTILITY ENGINES

Assumed Fraction Industrial Gasoline Engines Currently Double-Classified	Computed Industrial Gasoline Engine Average Horsepower	Average Value, Dollars (Fig. 24)
0	10	120
0.10	11	120
0.20	12	170
0.30	13	200
0.40	14	220
0.50	16	280
0.60	19	370
0.70	24	510
0.80	35	400
0.85	45	420
0.88	55	450
0.90	65	480
0.92	81	520
0.94	106	600

industrial diesel engines (where imports and exports are assumed to balance) and 990,000 for industrial gasoline engines (where 10% of production is assumed to be exported).

B. Development of Emission Factors for Industrial Engines

The duty-cycles of industrial engines are undoubtedly of many types, but no specific information is available on them which would permit computation of emission factors on a rigorous basis. In the absence of data, a duty cycle termed "general purpose industrial" will be used, with weighting factors as shown on the right side of Table 37 and composite emissions as shown at the bottom of Table 38 (called the "farm non-tractor" schedule in Tables 37 and 38). The general purpose industrial cycle is the same as both the farm non-tractor and general purpose construction cycles, with basis as discussed in section V. B. This cycle development was the final effort involved in achieving the secondary objective of modifying existing procedures, which was mentioned in section II.

Composite emissions for the category of industrial engines were determined by weighting emissions from each of the test engines as shown in Table 54. This weighting procedure is not an attempt to reconstruct the industrial engine population, but is rather intended to compute reasonable emission factors only. These category composite

TABLE 54. COMPUTATION OF COMPOSITE BRAKE SPECIFIC EMISSION FACTORS FOR INDUSTRIAL APPLICATIONS OF HEAVY-DUTY DIESEL AND GASOLINE ENGINES

Engine Type	Engine	*Assumed Fraction of Category hp hours	Contribution to Category Emission Factor, g/hphr HC	CO	NO_x	RCHO	SO_x	Part.
Industrial Diesel	Allis-Chalmers 3500	0.08	0.044	0.255	0.864	0.013	0.072	0.072
	Caterpillar D6C	0.05	0.005	0.045	0.239	0.004	0.043	0.020
	Detroit Diesel 6V-71	0.40	0.282	0.724	9.40	0.048	0.372	0.083
	International Har. D407	0.15	0.374	0.834	1.23	0.028	0.135	0.285
	John Deere 6404	0.07	0.225	0.209	0.388	0.060	0.066	0.094
	Mercedes-Benz OM636	0.05	0.052	0.188	0.142	0.013	0.055	0.100
	Onan DJBA	0.05	0.075	0.206	0.312	0.008	0.065	0.104
	Perkins 4.236	0.15	0.064	0.572	1.47	0.039	0.123	0.244
$\sum$ = Category	Composite Emission Factors =		1.12	3.03	14.0	0.21	0.931	1.00
Industrial Gasoline	Ford G5000 (G256)	0.35	2.07	50.4	2.40	0.10	0.083	0.114
	Hercules G-2300	0.40	2.38	76.0	1.57	0.064	0.103	0.096
	J. I. Case 159G	**0.05	0.383	14.4	0.110	0.028	0.014	0.015
	Wisconsin VH4D	0.20	1.85	58.6	1.08	0.028	0.068	0.102
$\sum$ = Category	Composite Emission Factors =		6.68	199.	5.16	0.22	0.268	0.327

*assumptions are arbitrary and do not reflect actual market or population percentages - see discussion p. 87

**low weight given the Case engine's emissions because it was erroneously run with high restrictions - see discussion p. 26

factors could be made much more rigorous if more data were available on the makeup of the population of industrial engines in service.

C. Estimation of National Impact for Industrial Engines

Using essentially the same methods as used for farm and construction engines, impact estimates have been made for emissions from industrial engines. The same assumptions on crankcase vent and evaporative losses were made for industrial engines as were made for construction engines (section VI. C.), except that all industrial engines were assumed to have evaporative losses of 3g/(gallon tank volume day). This latter factor is the same as assuming that half the gasoline engines had protected tanks and the other half had unprotected tanks. In addition, the annual days of usage for industrial engines was assumed to be the same as for construction engines in each region. When combined with the assumption that industrial engines are distributed in proportion to population (9.4% in the Northern region, 55.6% in the Central, and 35.0% in the Southern region)[38], the weighted mean season for use is 248 days, which is the period over which evaporative emissions were assumed to occur. For gasoline engines averaging 55 hp, the nominal fuel tank volume computed was 25 gallons.

Impact estimates based on the assumptions and data presented alone are given in Table 55. Gasoline engines appear to dominate the hydrocarbon and (especially) the CO emissions, while the diesels produce considerably more NO_x. Table 56 gives a comparison of industrial engine emissions to revised 1970 EPA Air Pollution Inventory Data[27], indicating that industrial engines make small but significant contributions only to national totals of CO and NO_x. Industrial engine contributions to hydrocarbons, SO_x, and particulate appear to be minimal.

To develop a breakdown of emissions from industrial engines on a seasonal, regional, and urban/rural basis, it will be necessa.y to make several assumptions. First, it will be assumed that industrial engines are distributed in proportion to population. It will also be assumed that the distribution of annual operating time follows that developed for estimation of evaporative emissions, and that the engine distribution among urban/suburban and rural areas is proportional to the (urban + suburban) and rural populations, respectively.

The results of this analysis are given in Table 57, indicating that about 74% of emissions from industrial engines may occur in urban/suburban areas. The table also shows that about 20% of industrial engine emissions occur in winter, 30% in the summer, and 25% each

TABLE 55. NATIONAL EMISSIONS IMPACT ESTIMATES FOR HEAVY-DUTY INDUSTRIAL ENGINES

Pollutant	Engine Type	g/unit yr $\times 10^{-3}$	ton/yr $\times 10^{-3}$	Total for Pollutant ton/yr $\times 10^{-3}$
HC (Exhaust)	Diesel	43.7	20.1	
	Gasoline	57.3	62.5	82.6
HC (Evaporative)	Gasoline	18.6	20.3	20.3
HC (Crankcase)	Gasoline	11.5	12.5	12.5
HC (Total)	Diesel	43.7	20.1	
	Gasoline	87.4	95.3	115.
CO	Diesel	118.	54.3	
	Gasoline	1710.	1860.	1910.
NO_x as NO_2	Diesel	546.	251.	
	Gasoline	44.3	48.3	299.
RCHO as HCHO	Diesel	8.2	3.8	
	Gasoline	1.9	2.1	5.9
SO_x as SO_2	Diesel	36.3	16.7	
	Gasoline	2.3	2.5	19.2
Particulate	Diesel	39.0	17.9	
	Gasoline	2.8	3.1	21.0

TABLE 56. COMPARISON OF HEAVY-DUTY INDUSTRIAL ENGINE EMISSIONS ESTIMATES WITH EPA NATIONWIDE AIR POLLUTANT INVENTORY DATA

	1970 EPA Inventory Data, 10^6 tons/yr[27] (Revised)		Heavy-Duty Industrial Engine Estimates as % of	
Pollutant	All Sources	Mobile Sources	All Sources	Mobile Sources
Hydrocarbons	27.3	15.2	0.421	0.757
CO	100.7	78.1	1.90	2.45
NO_x	22.1	11.0	1.42	2.72
SO_x	33.4	1.0	0.06	1.9
Particulate	25.5	0.9	0.08	2.33

in fall and spring. On a regional basis, about 8% of these emissions occur in the Northern region, 54% in the Central region, and 38% in the Southern region (regions defined in Appendix H). Compared to the distribution of population quoted earlier, the emission estimates are weighted less heavily toward the north and more heavily toward the south due to the graduation of assumed working season length from north to south.

TABLE 57. ESTIMATE OF SEASONAL, REGIONAL, AND URBAN-RURAL DISTRIBUTION OF EMISSIONS FROM INDUSTRIAL ENGINES

	Percentage of Annual Nationwide Emissions by Season								
	Urban/Suburban Areas				Rural Areas				
Region	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Subtotals
Northern	0.72	1.25	1.79	1.25	0.42	0.74	1.06	0.74	7.97
Central	7.66	10.21	12.76	10.21	2.44	3.26	4.07	3.26	53.87
Southern	6.16	6.92	7.69	6.92	2.32	2.61	2.90	2.61	38.13
Subtotals	14.54	18.38	22.24	18.38	5.18	6.61	8.03	6.61	
Totals	73.54				26.43				99.97

In summary, the major assumptions made in computation of national emissions impact for industrial engines were:

1. Engine shipments as reported by the Bureau of the Census[37], the total value of such shipments, and the values of the engines shipped according to power output can be used to estimate the average power output of industrial engines. (see pp. 84-86)

2. A high percentage of gasoline engines classified "industrial" in the Bureau of the Census statistics are actually in the light-duty engine category covered by an earlier report[36]. (see pp. 86 & 87)

3. Annual usage of industrial engines is approximately one-half that of construction engines of similar power output, and service life is 2500 hr for gasoline engines and 5000 hr for diesel engines. Population of industrial engines can be estimated using the Bureau of the Census shipment figures and the service life and annual usage estimates just given. (see pp. 86 & 87)

4. Emissions from heavy duty industrial engines can be estimated by combining results of tests conducted under the subject program in a reasonable way. (see pp. 87-89)

5. Engine operating cycles can be estimated by considering the type of operation most industrial engines undergo in the field. (see pp. 58 & 59)

VIII. SUMMARY

This report is the end product of a study on emissions from heavy-duty diesel and gasoline engines used in farm, construction, and industrial applications. It is Part 5 of a planned seven-part final report on "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines," Contract EHS 70-108. The report includes test data, documentation, and discussion on detailed emissions characterization of eight diesel engines and four gasoline engines, as well as estimated emission factors and national emissions impact for each of the three applications separately. As a part of the final report on the characterization phase of EHS 70-108, this report does not include information on aircraft turbine emissions, outboard motor crankcase drainage, or locomotive emissions control technology. As required by the contract, these three latter areas have been or will be reported on separately.

Emission measurements on the twelve heavy-duty engines were conducted in the Emissions Research Laboratory, utilizing several electric engine dynamometers. Most of the data were acquired by operating the engines on the "21-mode" or "23-mode" mapping procedures or some variation thereof, with the exception of "transient" smoke data acquired by using the Federal smoke test procedure. Gaseous emission measurements were also acquired during transient operation, but the results did not justify a detailed analysis.

The exhaust products measured included total hydrocarbons by FIA; CO, CO_2, NO, and hydrocarbons (HC for gasoline engines only) by NDIR; O_2 by electrochemical analysis; light hydrocarbons by gas chromatograph; aldehydes by wet chemistry; particulate by gravimetric analysis; and smoke (diesel engines only) by the PHS light extinction smokemeter. Evaporative losses of gasoline, crankcase vent hydrocarbon emissions from gasoline engines, and SO_x emissions were calculated rather than being measured. Emission factors and national impact were computed (separately for each of the three applications) for total hydrocarbons, CO, NO_x, RCHO (aldehydes), particulate, and SO_x.

Reiterating qualifications given earlier in the text, the major assumptions made in computation of national emissions impact for farm equipment were:

1. The 1972 populations of farm tractors and other major items of powered farm equipment are correct as given in the literature. (see pp. 47, 48, 54 & 56)

2. Tractor usage in hr/yr can be approximated by 450 + 3.89 (hp-50) - 5.45 (age, yr). (see pp. 54 & 55)

3. Total operating time for equipment except tractors

can be estimated from total U. S. crop average (see pp. 57 & 58)

4. The fraction of tractors of age A_i still surviving can be approximated by $F_i = S_i N_i = e^{-0.00155A_i^2}$. (see pp. 49, 50, & 55)

5. Diesel and gasoline horsepower in the field can be approximated using the following considerations; (see pp. 49, 51-54)
   a. large tractors are predominantly diesel
   b. small tractors (considering entire population) are predominantly gasoline
   c. diesel market penetration is proportional to machine size and is increasing linearly with time.

6. Engine operating cycles can be estimated from manufacturers' operating data, and from consideration of the type of operation each type of engine undergoes in the field. (see pp. 58-60)

7. Emissions from heavy duty farm engines can be estimated by combining results of tests conducted under the subject program in a reasonable way. (see pp. 61-63)

The major assumptions made in computation of national emissions impact for construction equipment were:

1. The service life of construction machinery is 10,000 to 12,000 hours, and the average horsepower of machines in several categories is as shown on the next page. (see pp. 68 & 69)

2. Annual operating time for construction machines can be approximated by

$$\text{usage (hr/yr)} = 500 + 0.1\,(\text{hp})^{1.8};$$

   except for tracklaying shovel loaders, off-highway trucks, and scrapers, for which other data are available. (see pp. 69 & 70)

3. The life of construction equipment (in years), computed from service life (in hours) and usage, can be used with typical annual shipments to estimate number of units in service, as shown on the next page. (see pp. 69 & 71).

TABULATION OF PERTINENT ASSUMPTIONS AND COMPUTED VALUES FOR CONSTRUCTION EQUIPMENT

Category	Assumed Service Life, hr	Assumed Avg. hp	Annual Operation, hr/yr	Computed Life, yr	Typical Total Annual Shipments	*Domestic Shipments Over Computed Average Life
Track Tractors	10,000	120	1050	9.5	23,000	197,000
Track Shovel Loaders	10,000	65	1100	9.1	10,500	86,000
Motor Graders	12,000	90	830	14.5	7,300	95,300
Scrapers	12,000	475	2000	6.0	5,000	27,000
Off-Hwy. Trucks	12,000	400	2000	6.0	3,850	20,800
Wheel Loaders	12,000	130	1140	10.5	14,200	134,000
Wheel Tractors	12,000	75	740	16.2	30,000	437,000
Rollers	12,000	75	740	16.2	5,600	81,600
Wheel Dozers	12,000	300	2000	6.0	500	2,700
General Purpose	-	120	1000	-	-	100,000

*including assumption of 10% exports

4. Emissions from construction engines can be estimated by combining results of tests conducted under the subject program in a reasonable way. (see pp. 70 & 79)

5. Engine operating cycles can be estimated from manufacturers' operating data. (see pp. 71-77)

The major assumptions made in computation of national emissions impact for industrial engines were:

1. Engine shipments as reported by the Bureau of the Census[37], the total value of such shipments, and the values of the engines shipped according to power output can be used to estimate the average power output of industrial engines. (see pp. 84-86)

2. A high percentage of gasoline engines classified "industrial" in the Bureau of the Census statistics are actually in the light-duty engine category covered by an earlier report[36]. (see pp. 86 & 87)

3. Annual usage of industrial engines is approximately one-half that of construction engines of similar power output, and service life is 2500 hr for gasoline engines and 5000 hr for diesel engines. Population of industrial engines can be estimated using the Bureau of the Census shipment figures and the service life and annual usage estimates just given. (see pp. 86 & 87)

4. Emissions from industrial engines can be estimated by combining results of tests conducted under the subject program in a reasonable way. (see pp. 87-89)

5. Engine operating cycles can be estimated by considering the type of operation most industrial engines undergo in the field. (see pp. 58 & 59)

The estimates of total emissions impact made in this report are on the basis of engine populations, annual usage, and engine size and type, rather than on the basis of fuel consumed by the category as a whole. The decision to base estimates on work output was made for two major reasons. First, assumptions such as annual usage and population composition are easier to deal with in terms of personal experience than a number for overall fuel consumption which is nearly impossible to check. It is also more straightforward to check the smaller assumptions statistically, should it be considered desirable at some point to generate more accurate impact estimates. Second, the validity of overall fuel usage data is very much in doubt. The Bureau of Mines off-highway diesel fuel estimates[39, 40], for instance, do not include any heating oil used in off-highway equipment, and all diesel fuel sold by distributors who sell less than 420,000 gallons of distillate fuel annually is not reported at all. Furthermore, considering any sort of realistic need on the part of agriculture, construction, and industry, the Bureau of Mines off-highway diesel fuel usage estimates simply seem unreasonably low.

Data on gasoline usage by the Department of Transportation[41] seem closer to fact, but even these estimates of off-highway gasoline usage are undoubtedly low because.

1. Gasoline used in lawn, garden, and recreational engines, outboard motors, and off-road vehicles is largely purchased through normal retail outlets. Such fuel is taxed and included with <u>on-road</u> fuel estimates.

2. Construction and industrial concerns which operate both highway and off-highway equipment often buy fuel for all uses at once, and do not go to the trouble of securing tax exemption for the (sometimes relatively small) amounts used in off-highway equipment. The part used off-highway is thus taxed and included with <u>on-road</u> fuel estimates.

For clarity, estimated emissions from F, C, & I engines as percentages of <u>revised</u> 1970 national totals from all sources and mobile sources are presented in the following tabulation. As shown above,

National Total Used for Comparison	Application	Percent of National Total for Pollutant				
		HC	CO	NO_x	SO_x	Part.
All Sources 1970 (Revised)	Farm	1.0	3.8	2.2	0.11	0.21
	Construction	0.47	1.3	3.9	0.20	0.26
	Industrial	0.42	1.9	1.4	0.06	0.08
Mobile Sources 1970 (Revised)	Farm	1.9	4.9	4.5	3.7	6.1
	Construction	0.84	1.7	7.8	6.7	7.2
	Industrial	0.76	2.4	2.7	1.9	2.3

these estimates are highly qualified, and should be used only with full knowledge of the accuracy of data and assumptions used in arriving at them. In the regional order Northern-Central-Southern, emissions from farm engines are estimated to be distributed 16%-49%-35%, those from construction engines 8%-50%-42%, and those from industrial engines 8%-54%-38%. It is also estimated that 75% of construction equipment emissions and 74% of industrial engine emissions occur in urban/suburban areas, while virtually all emissions from farm equipment occur in rural areas.

The categories of engines covered in this report appear to make some significant, but not major, contributions to national pollutant totals from man-made sources. It should be recognized, however, that the estimates are based on many assumptions and data items which are unproven, but as reasonable as possible. If more precise estimates are to be made, a great deal of quantitative information on engine population and usage must be gathered as a prerequisite.

LIST OF REFERENCES

1. Federal Register, Vol. 37, No. 221 Part II, Subparts H and J, November 15, 1972.

2. R. G. Bascom and G. C. Hass, "A Status Report on the Development of the 1973 California Diesel Emissions Standards." SAE Paper No. 700671, 1970.

3. Sawicki, E., et al, The 3-Methyl-3-benzathiazalone Hydrazone Test, Anal, Chem. 33:93, 1961.

4. Altshuller, A. P., et al, Determination of Formaldehyde in Gas Mixtures by the Chromotropic Acid Method, Anal, Chem. 33:621, 1961.

5. S. R. Krause, "Effect of Engine Intake-Air Humidity, Temperature, and Pressure on Exhaust Emissions." SAE Paper No. 710835, 1971.

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

7. D. T. Wade, "Factors Influencing Vehicle Evaporative Emissions." SAE Paper No. 670126, 1967.

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

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

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

11. P. A. Bennett, et al, "Reduction of Air Pollution by Control of Emissions from Automotive Crankcases," Paper No. 142A presented January 1960 at the SAE Annual Meeting.

12. G. M. Heinen, "We've Done the Job - What's Next?" SAE Paper No. 690539, 1969.

13. Optical Properties and Visual Effects of Smoke-Stack Plumes, A cooperative study: Edison Electric Institute and U.S. Public Health Service, Publication No. 999-AP-30, Cincinnati, 1967.

14. John O. Storment and Karl J. Springer, "Evaluation of Diesel Smoke Inspection Procedures and Smokemeters." Final Report by Southwest Research Institute to the Environmental Protection Agency on Contract EHS 70-109, July 1972.

15. Confidential Emissions Data From Three Manufacturers Submitted to C. T. Hare of SwRI at the Request of the Project Officer.

16. W. F. Marshall and R. D. Fleming, "Diesel Emissions Reinventoried." Report of Investigations 7530 by the U.S. Department of the Interior, Bureau of Mines, 1972.

17. John O. Storment and Karl J. Springer, "A Surveillance Study of Smoke from Heavy-Duty Diesel-Powered Vehicles Southwestern U.S.A." Final Report to the Environmental Protection Agency on Contract EHS 70-109, June 1973.

18. Data Submitted to Karl J. Springer by A. H. Glasenapp, Experimental Engineering Section of Engineering Division, Truck and Coach Division of General Motors Corporation.

19. R. D. Henderson, "Air Pollution and Construction Equipment." SAE Paper No. 700551, 1970.

20. Implement & Tractor magazine, Statistical Issues from 1964 through 1972, "Red Book" Specification Issues, and Others.

21. Information on Farm Tractor and Industrial Equipment Population and Usage Sent to SwRI by Mr. James W. Walker (John Deere), Chairman of the EMA-OAP Emissions Survey Subcommittee. Sources Referenced Include SAE Papers, EPA Reports, Manufacturers' Data, Implement & Tractor magazine, and Statistical Abstracts of the United States.

22. Implement & Tractor magazine, April 7, 1967.

23. Information on Farm Tractor Duty Cycles and Annual Usage Sent to C. T. Hare by Mr. John H. Crowley (J. I. Case), Past Chairman of the EMA-OAP Emissions Survey Subcommittee. Sources Referenced Include Agricultural Engineering (May 1961 and February 1969), Detroit Diesel-Allison Division of General Motors Corporation, and John Deere Company.

24. Statistical Abstracts of the United States, 1971.

25. Implement & Tractor magazine, February 7, 1973, Referencing an ASAE Paper, "A Projection of New Problems and Opportunities for Tractor Safety," by Prof. Richard G. Pfister, Michigan State University.

26. Bainer, et al, Principles of Farm Machinery, John Wiley & Sons, New York, 1955.

27. 1970 EPA Air Pollution Inventory Estimates (revised), 1973 Annual Report of the Council on Environmental Quality.

28. Automotive Industries Statistical Issues, 1960-1973.

29. Current Industrial Reports, Construction Machinery 1970 (and Other Years), Series MA-35D(70)-1, U.S. Department of Commerce, Bureau of the Census.

30. R. D. Henderson, "Digging Into Air Pollution Problems--An Earthmover's Viewpoint." SAE Paper No. 720609, 1972.

31. Information on Construction Equipment Duty Cycles Sent to C. T. Hare by Mr. John H. Crowley (J. I. Case), Past Chairman of the EMA-OAP Emissions Survey Subcommittee. Sources Referenced are Allis-Chalmers and Detroit Diesel-Allison Division of General Motors Corporation.

32. Confidential Sales Data from a Manufacturer, Submitted to C. T. Hare of SwRI.

33. Construction Methods & Equipment, November and December 1972.

34. Construction Equipment, February 1973.

35. Construction Methods & Equipment, December 1972.

36. Charles T. Hare and Karl J. Springer, "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines." Final Report Part 4, Small Air-Cooled Spark Ignition Utility Engines, Contract EHS 70-108 with the Environmental Protection Agency, May 1973.

37. Current Industrial Reports, Internal Combustion Engines 1971 (and Prior Years to 1964), Series MA-35L(71)-1, U.S. Department of Commerce, Bureau of the Census.

38. The World Almanac, 1972 Edition, Luman H. Long (ed), Newspaper Enterprise Association, Inc., New York, 1971.

39. Sales of Fuel Oil and Kerosine in 1965 (1966, 1968, 1969, 1970), Mineral Industry Surveys, U. S. Department of the Interior, Bureau of Mines.

40. (form for reporting of) Fuel Oil and Kerosine Sales and Inventories (by individual companies), U. S. Department of the Interior, Bureau of Mines.

41. State Motor-Fuel Tax Receipts, Table MF-1 (1968-1971); Motor-Fuel Consumption, Table MF-2 (1968-1971); Analysis of Private and Commercial Use of Gasoline for Nonhighway Purposes, Table MF-24 (1968-1971); U. S. Department of Transportation, FHA, Bureau of Public Roads.

APPENDIX A

GRAPHICAL PRESENTATION OF EMISSIONS FROM DIESEL ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

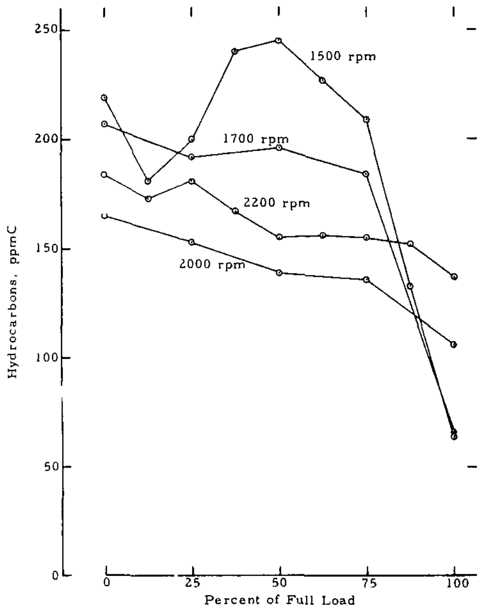

FIGURE A-1. HYDROCARBON EMISSIONS FROM AN ALLIS-CHALMERS 3500 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

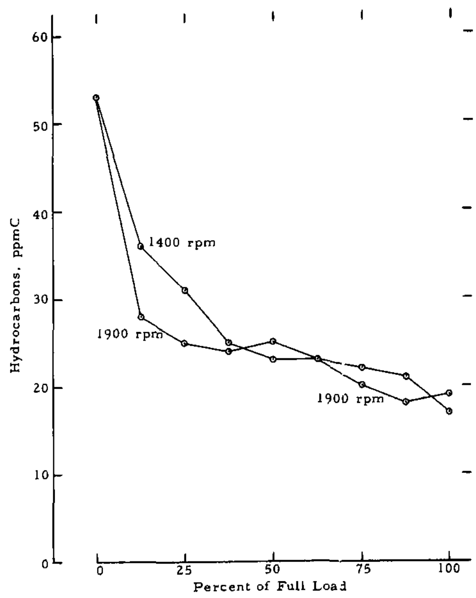

FIGURE A-2. HYDROCARBON EMISSIONS FROM A CATERPILLAR D6C ENGINE AS A FUNCTION OF LOAD AT TWO SPEEDS

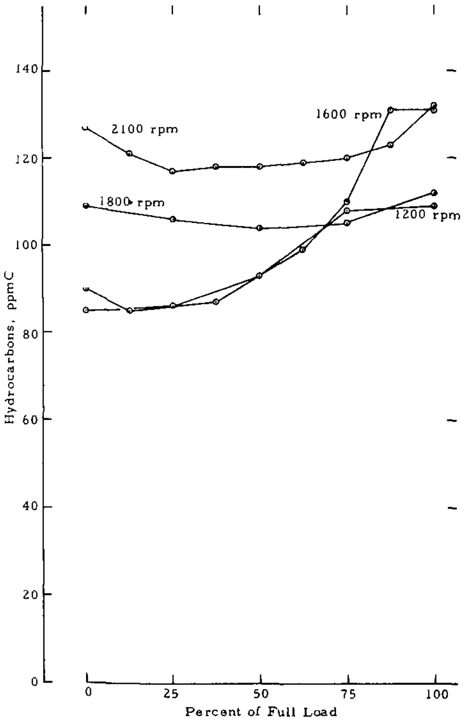

FIGURE A-3. HYDROCARBON EMISSIONS FROM A DETROIT DIESEL 6V-71 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

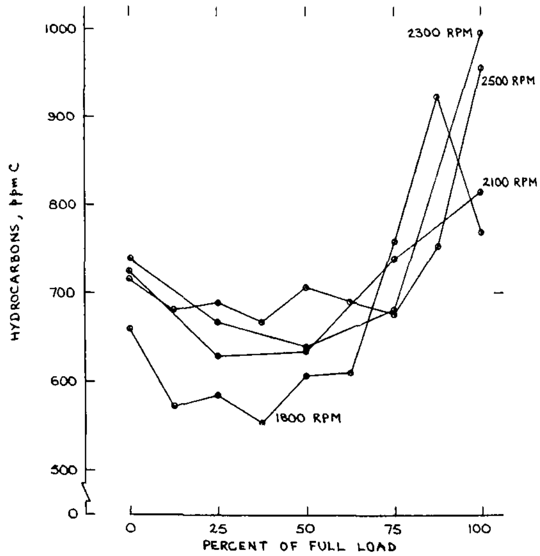

FIGURE A-4. HYDROCARBON EMISSIONS FROM AN INTERNATIONAL HARVESTER D407 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

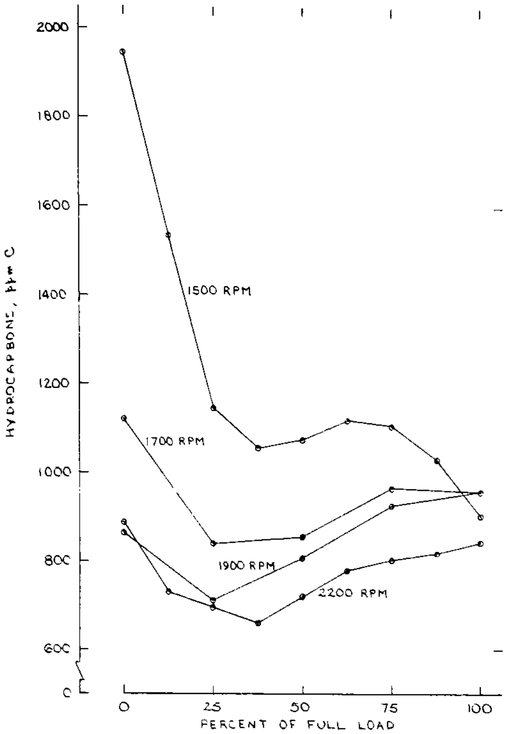

FIGURE A-5 HYDROCARBON EMISSIONS FROM A JOHN DEERE 6404 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

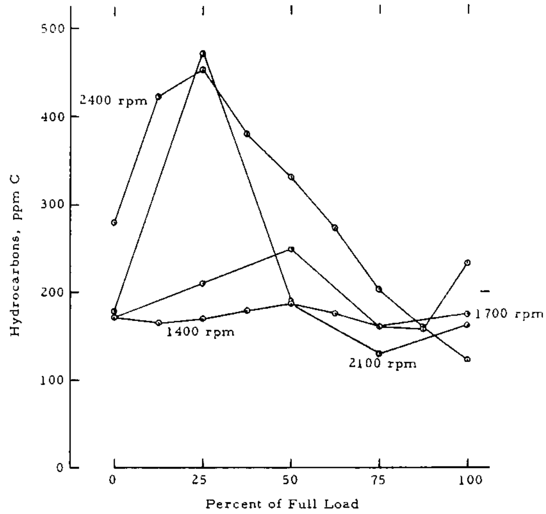

FIGURE A-6. HYDROCARBON EMISSIONS FROM A MERCEDES-BENZ OM636 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

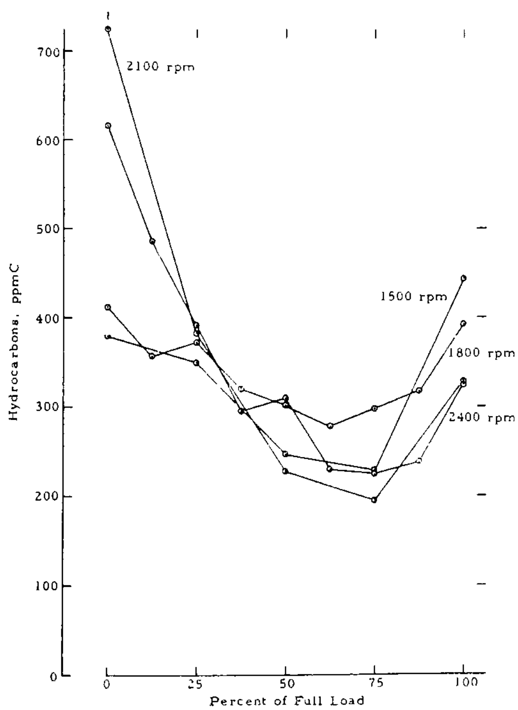

FIGURE A-7. HYDROCARBON EMISSIONS FROM AN ONAN DJBA ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

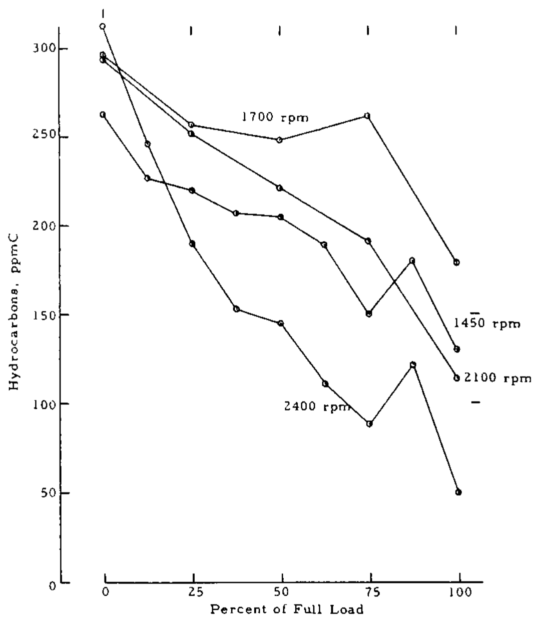

FIGURE A-8. HYDROCARBON EMISSIONS FROM A PERKINS 4.236 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

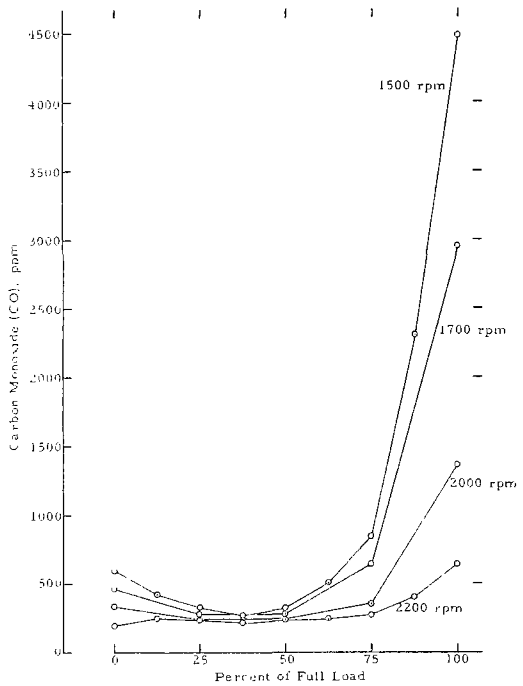

FIGURE A-9. CARBON MONOXIDE EMISSIONS FROM AN ALLIS-CHALMERS 3500 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

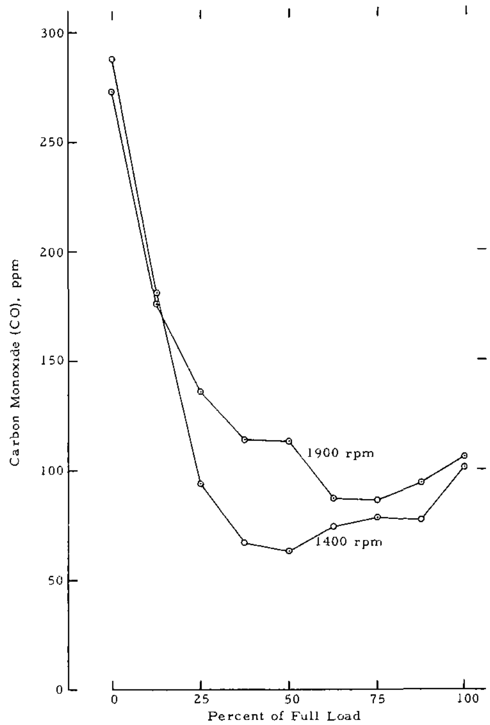

FIGURE A-10. CARBON MONOXIDE EMISSIONS FROM A CATERPILLAR D6C ENGINE AS A FUNCTION OF LOAD AT TWO SPEEDS

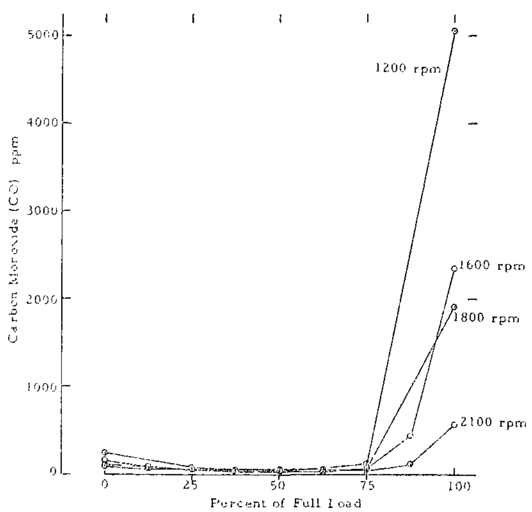

FIGURE A-11 CARBON MONOXIDE EMISSIONS FROM A DETROIT DIESEL 6V-71 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

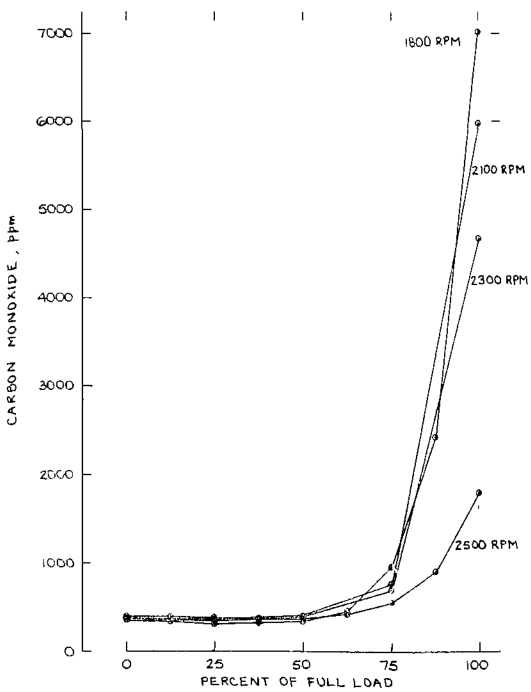

FIGURE A-12. CARBON MONOXIDE EMISSIONS FROM AN INTERNATIONAL HARVESTER D407 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

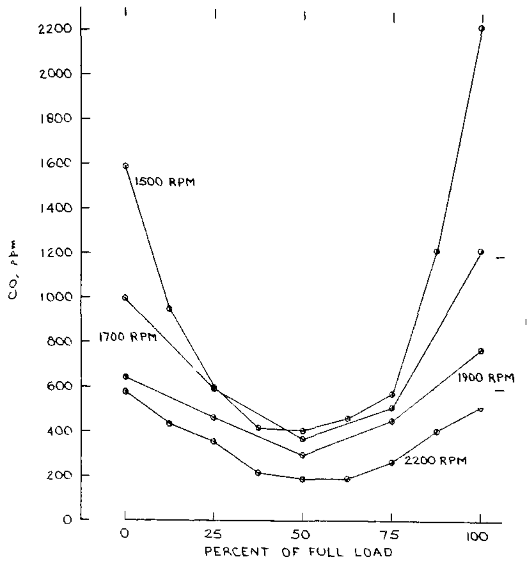

FIGURE A-13. CARBON MONOXIDE EMISSIONS FROM A JOHN DEERE 6404 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

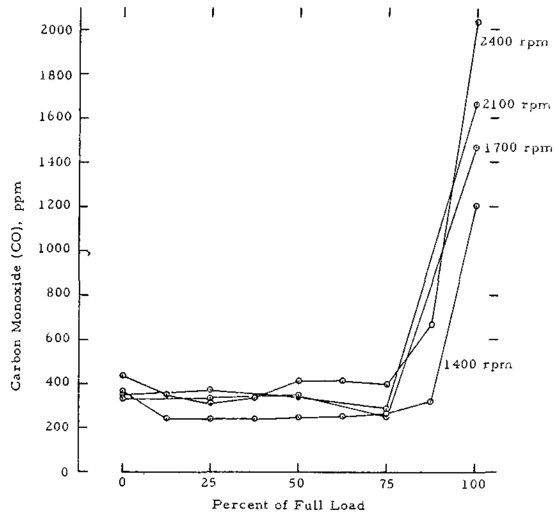

FIGURE A-14. CARBON MONOXIDE EMISSIONS FROM A MERCEDES-BENZ OM636 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

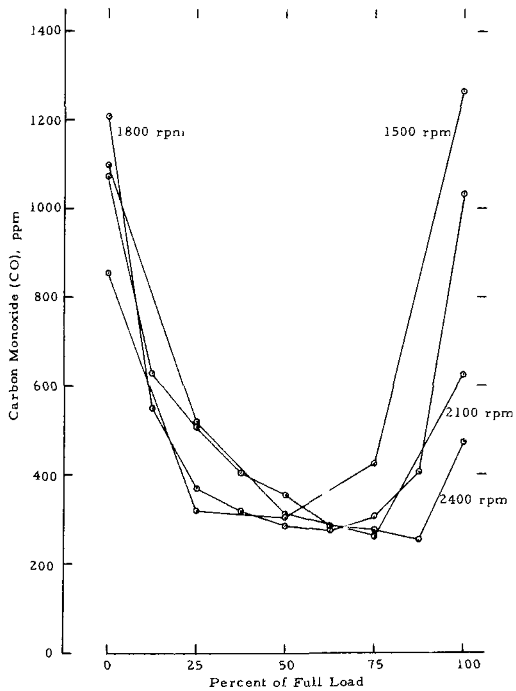

FIGURE A-15. CARBON MONOXIDE EMISSIONS FROM AN ONAN DJBA ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

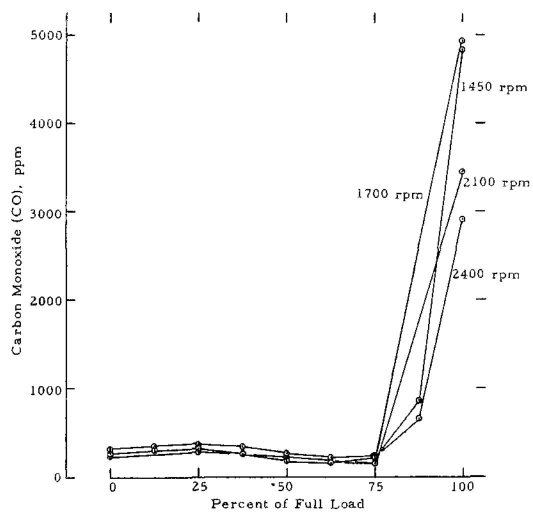

FIGURE A-16. CARBON MONOXIDE EMISSIONS FROM A PERKINS 4.236 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

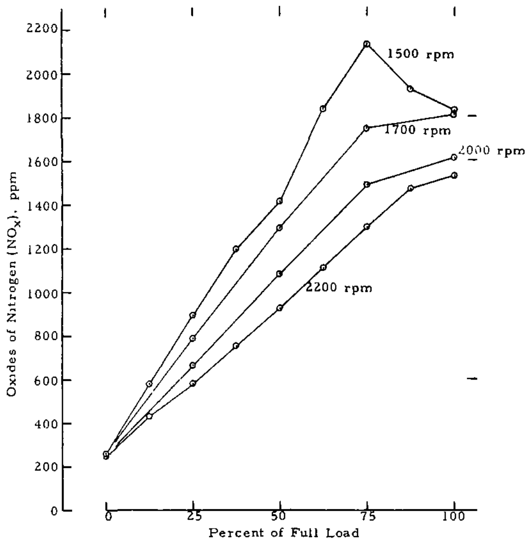

FIGURE A-17. OXIDES OF NITROGEN EMISSIONS FROM AN ALLIS-CHALMERS 3500 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

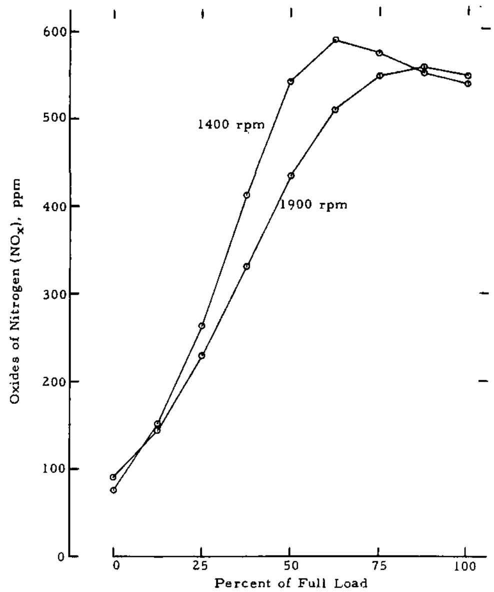

FIGURE A-18. OXIDES OF NITROGEN EMISSIONS FROM A CATERPILLAR D6C ENGINE AS A FUNCTION OF LOAD AT TWO SPEEDS

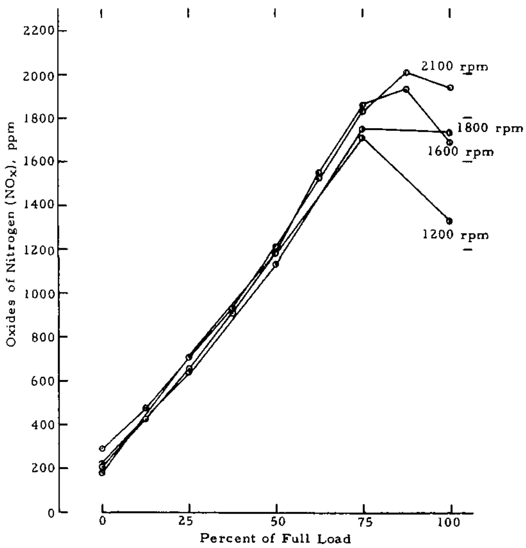

FIGURE A-19. OXIDES OF NITROGEN EMISSIONS FROM A DETROIT DIESEL 6V-71 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

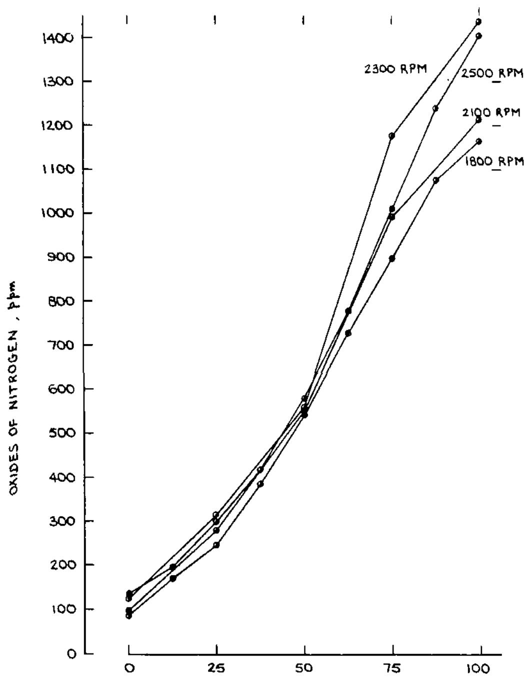

FIGURE A-20. OXIDES OF NITROGEN EMISSIONS FROM AN INTERNATIONAL HARVESTER D407 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

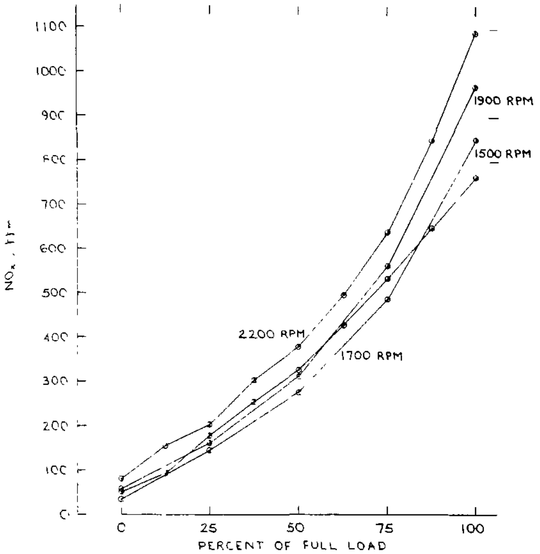

FIGURE A-21. OXIDES OF NITROGEN EMISSIONS FROM A JOHN DEERE 6404 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

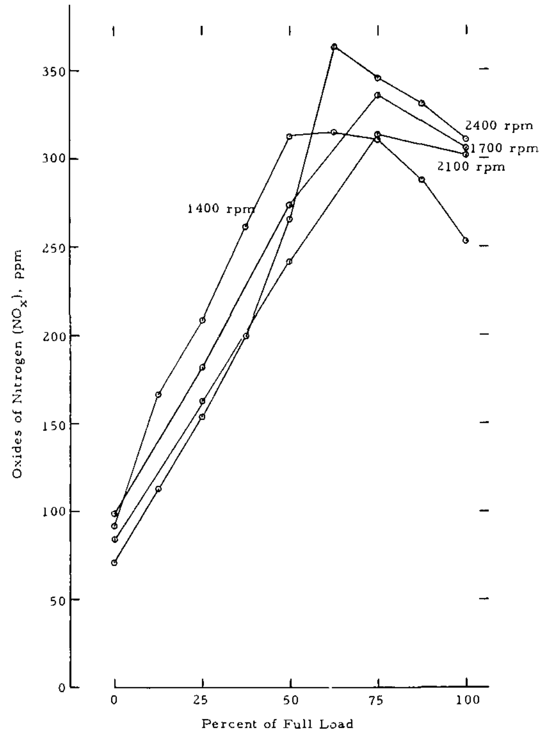

FIGURE A-22. OXIDES OF NITROGEN EMISSIONS FROM A MERCEDES-BENZ OM636 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

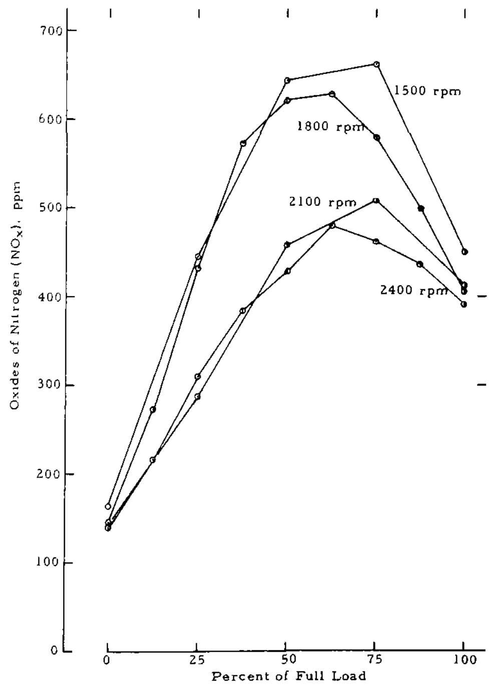

FIGURE A-23. OXIDES OF NITROGEN EMISSIONS FROM AN ONAN DJBA ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

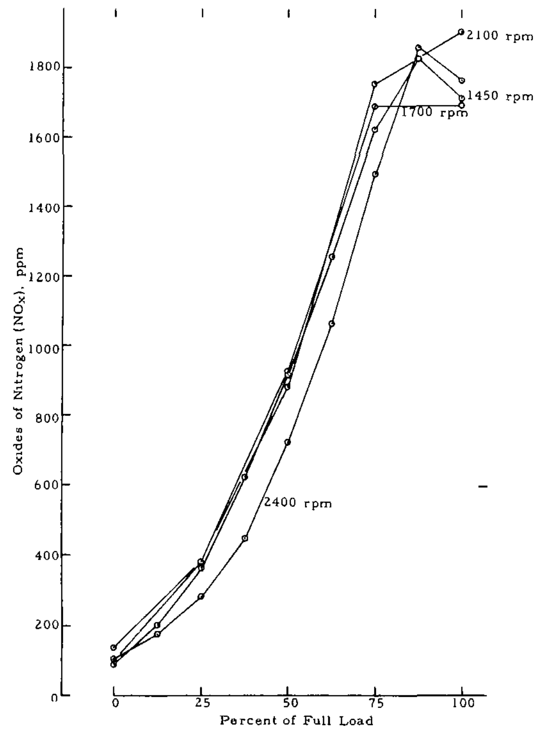

FIGURE A-24. OXIDES OF NITROGEN EMISSIONS FROM A PERKINS 4.236 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

APPENDIX B

DATA FROM FEDERAL SMOKE TESTS ON DIESEL ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

FEDERAL SMOKE TRACE EVALUATION

Vehicle ________ Date 11/22/72 Evaluated by J.W.

Engine Model ALLIS-CHALMERS 3500 Run No. 1

Accelerations

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	27.5	1	27.0	1	29.0
2	38.5	2	37.2	2	36.5
3	43.3	3	38.0	3	43.2
4	46.0	4	41.5	4	48.0
5	44.0	5	40.0	5	48.5
6	38.5	6	40.5	6	42.0
7	36.0	7	36.5	7	39.0
8	36.0	8	35.0	8	40.0
9	31.0	9	33.5	9	36.0
10	31.5	10	33.0	10	31.5
11	51.0	11	28.5	11	32.5
12	40.0	12	44.5	12	49.0
13	34.0	13	38.0	13	42.0
14	31.5	14	33.5	14	34.5
15	27.5	15	28.5	15	28.5

Total Smoke % 556.3 535.2 580.2

Factor (a) $\frac{1671.7}{45}$ = 37.2 %

Lugging

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	29.0	1	28.0	1	30.0
2	29.0	2	28.5	2	30.5
3	31.2	3	29.0	3	29.5
4	29.0	4	28.5	4	31.0
5	29.5	5	30.5	5	32.0

Total Smoke % 147.7 144.5 153.0

Factor (b) $\frac{445.2}{15}$ - 29.7 %

Peak Readings

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
11A	51.0	12A	44.5	12A	49.0
4A	46.0	4A	41.5	5A	48.5
5A	44.0	6A	40.5	4A	48.0

Total Smoke % 141.0 126.5 145.5

Factor (c) - $\frac{413.0}{9}$ - 45.9 %

FEDERAL SMOKE TRACE EVALUATION

Vehicle —————— Date 1/10/72 Evaluated by J. W.
Engine Model CATERPILLAR D6C Run No. 1

Accelerations

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	8.5	1	8.5	1	9.0
2	8.5	2	9.0	2	10.0
3	8.2	3	6.4	3	9.2
4	7.5	4	6.0	4	7.0
5	5.5	5	6.5	5	4.5
6	5.0	6	3.5	6	4.1
7	3.0	7	3.0	7	3.0
8	2.6	8	3.0	8	4.0
9	2.0	9	3.2	9	3.0
10	3.0	10	3.5	10	4.5
11	6.0	11	3.4	11	3.5
12	2.9	12	2.1	12	4.5
13	2.7	13	2.0	13	3.8
14	2.2	14	2.6	14	2.4
15	2.5	15	2.1	15	2.6
Total Smoke %	70.5		64.8		75.1

Factor (a) - $\frac{210.4}{45}$ = 4.7%

Lugging

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	2.5	1	2.5	1	2.2
2	2.2	2	2.5	2	2.4
3	2.4	3	2.7	3	3.0
4	2.9	4	2.6	4	1.6
5	2.3	5	2.1	5	2.2
Total Smoke %	12.3		12.4		11.4

Factor (b) - $\frac{36.1}{15}$ - 2.4 %

Peak Readings

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1 A	8.5	1 A	8.5	1 A	9.0
2 A	8.5	2 A	9.0	2 A	10.0
3 A	8.2	5 A	6.5	3 A	9.2
Total Smoke %	25.2		24.0		28.2

Factor (c) - $\frac{77.4}{9}$ = 8.6 %

FEDERAL SMOKE TRACE EVALUATION

Vehicle ________________ Date 10/12/72 Evaluated by J. W.

Engine Model DETROIT DIESEL 6V-71 Run No. 1

Accelerations

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	3.0	1	2.0	1	2.0
2	4.0	2	2.8	2	4.3
3	3.3	3	3.0	3	4.3
4	3.2	4	3.2	4	3.7
5	2.8	5	2.5	5	2.2
6	2.7	6	1.9	6	2.0
7	1.7	7	1.3	7	1.8
8	1.3	8	1.1	8	1.2
9	1.1	9	0.9	9	1.1
10	1.0	10	0.8	10	1.0
11	1.0	11	0.7	11	0.9
12	1.0	12	0.7	12	0.9
13	1.0	13	0.6	13	0.9
14	0.9	14	0.6	14	0.9
15	0.9	15	0.6	15	0.9
Total Smoke %	28.9		22.7		28.1

Factor (a) $\frac{79.7}{45}$ = 1.9 %

Lugging

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	1.7	1	1.2	1	2.0
2	1.3	2	1.2	2	1.1
3	1.3	3	0.9	3	1.0
4	1.6	4	0.9	4	1.0
5	1.4	5	0.9	5	1.0
Total Smoke %	7.3		5.1		6.1

Factor (b) $\frac{18.5}{15}$ = 1.2 %

Peak Readings

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
2A	4.0	4A	3.2	2A	4.3
3A	3.3	3A	3.0	3A	4.3
4A	3.2	2A	2.8	4A	3.7
Total Smoke %	10.5		9.0		12.3

Factor (c) = $\frac{31.8}{9}$ = 3.5 %

FEDERAL SMOKE TRACE EVALUATION

Vehicle ______________ Date 5/24/72 Evaluated by J.W.

Engine Model I.H. D407 Run No. 1

Accelerations

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	24.0	1	32.0	1	22.0
2	37.3	2	28.2	2	30.3
3	28.0	3	23.6	3	27.5
4	25.0	4	21.0	4	23.5
5	21.0	5	17.5	5	19.3
6	18.2	6	15.9	6	17.7
7	16.1	7	13.0	7	15.0
8	14.9	8	12.6	8	14.5
9	14.0	9	14.2	9	13.0
10	13.7	10	13.5	10	12.6
11	13.6	11	11.3	11	14.5
12	13.1	12	13.4	12	12.8
13	11.7	13	12.5	13	12 4
14	11.1	14	11.4	14	12.0
15	12.6	15	12.1	15	11.4
Total Smoke %	274.3		252.2		259.5

Factor (a) = $\frac{786.0}{45}$ = 17.5 %

Lugging

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	18.0	1	19.0	1	18.0
2	18.7	2	20.1	2	18.3
3	19.2	3	20.5	3	18.6
4	18.8	4	19.4	4	17.9
5	18.4	5	18.8	5	18.4
Total Smoke %	93.1		97.8		91.2

Factor (b) $\frac{282.1}{15}$ = 18.8 %

Peak Readings

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
2 A	37.3	1 A	32.0	2 A	30.3
3 A	28.0	2 A	28.2	3 A	27.5
4 A	25.0	3 A	23.6	4 A	23.5
Total Smoke %	90.3		83.8		81.3

Factor (c) = $\frac{255.4}{9}$ = 28.4 %

FEDERAL SMOKE TRACE EVALUATION

Vehicle ________ Date 3/8/72 Evaluated by J.W.

Engine Model DEERE 6404 Run No. 1

Accelerations

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	80.0	1	85.6	1	75.0
2	77.5	2	76.0	2	84.0
3	75.9	3	81.8	3	79.3
4	69.3	4	86.6	4	86.0
5	67.0	5	87.3	5	69.0
6	72.5	6	81.0	6	62.0
7	67.7	7	69.9	7	61.0
8	67.8	8	69.1	8	69.0
9	64.8	9	71.0	9	57.6
10	59.0	10	59.0	10	54.0
11	56.5	11	50.0	11	50.0
12	46.0	12	44.0	12	43.0
13	40.5	13	44.5	13	34.0
14	45.0	14	49.0	14	61.8
15	50.0	15	42.5	15	47.5
Total Smoke %	939.5		1017.3		933.2

Factor (a) $\frac{2890.0}{45}$ = 64.2%

Lugging

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	21.0	1	24.0	1	22.5
2	22.5	2	26.0	2	21.5
3	22.0	3	27.0	3	24.5
4	24.5	4	26.8	4	24.4
5	29.0	5	27.5	5	32.1
Total Smoke %	119.0		131.3		125.0

Factor (b) $\frac{375.3}{15}$ 25.0%

Peak Readings

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1A	80.0	1A	85.6	2A	84.0
2A	77.5	4A	86.6	3A	79.3
3A	75.9	5A	87.3	4A	86.0
Total Smoke %	233.4		259.5		249.3

Factor (c) = $\frac{742.2}{9}$ = 82.4%

FEDERAL SMOKE TRACE EVALUATION

Vehicle ____________ Date 1/26/73 Evaluated by K. H.

Engine Model MERCEDES OM636 Run No. 1

Accelerations

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	12.0	1	12.5	1	19.0
2	18.5	2	14.5	2	10.5
3	8.5	3	9.5	3	11.0
4	8.8	4	10.0	4	9.5
5	9.0	5	9.0	5	8.0
6	7.3	6	8.0	6	7.3
7	7.6	7	8.2	7	11.0
8	9.5	8	10.0	8	10.0
9	7.5	9	11.0	9	9.1
10	6.8	10	9.6	10	8.3
11	7.0	11	6.5	11	8.0
12	7.3	12	12.0	12	9.5
13	8.0	13	11.0	13	9.0
14	7.0	14	7.4	14	10.0
15	7.0	15	8.0	15	10.0

Total Smoke % 131.8   147.2   150.2

Factor (a) $\frac{429.2}{45}$ - 9.5 %

Lugging

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	9.8	1	10.0	1	11.5
2	11.2	2	8.8	2	9.5
3	9.5	3	10.0	3	10.4
4	10.2	4	10.5	4	13.0
5	10.0	5	9.5	5	13.5

Total Smoke % 50.7   48.8   57.9

Factor (b) $\frac{157.4}{15}$ 10.5%

Peak Readings

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
2A	18.5	2A	14.5	1A	19.0
1A	12.0	1A	12.5	5L	13.5
2L	11.2	12A	12.0	4L	13.0

Total Smoke % 41.7   39.0   45.5

Factor (c) = $\frac{126.2}{9}$ 14.0 %

FEDERAL SMOKE TRACE EVALUATION

Vehicle ____________ Date 10/6/72 Evaluated by J.W.

Engine Model PERKINS 4.236 Run No. 1

Accelerations

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	15.0	1	8.5	1	12.5
2	6.5	2	8.5	2	8.5
3	4.7	3	4.6	3	4.8
4	6.4	4	4.5	4	5.7
5	6.0	5	6.2	5	6.1
6	4.5	6	6.0	6	5.3
7	4.4	7	5.2	7	4.7
8	4.6	8	4.5	8	3.9
9	5.2	9	4.5	9	3.9
10	5.2	10	4.5	10	4.2
11	5.0	11	4.5	11	3.9
12	5.4	12	4.6	12	4.0
13	5.5	13	4.5	13	4.0
14	5.8	14	5.2	14	4.4
15	5.5	15	6.0	15	4.4
Total Smoke %	89.7		81.8		80.3

Factor (a) - $\frac{251.8}{45}$ 5.6 %

Lugging

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1	8.5	1	9.0	1	7.6
2	9.5	2	8.5	2	6.8
3	8.5	3	8.5	3	8.2
4	8.5	4	9.5	4	7.3
5	8.9	5	9.5	5	8.5
Total Smoke %	43.9		45.0		38.4

Factor (b) $\frac{127.3}{15}$ 8.5 %

Peak Readings

First Sequence		Second Sequence		Third Sequence	
Interval No.	Smoke %	Interval No.	Smoke %	Interval No.	Smoke %
1A	15.0	4L	9.5	1A	12.5
2L	9.5	5L	9.5	2A	8.5
5L	8.9	1L	9.0	5L	8.5
Total Smoke %	33.4		28.0		29.5

Factor (c) = $\frac{90.9}{9}$ - 10.1 %

APPENDIX C

TABULAR PERFORMANCE AND EMISSIONS DATA ON DIESEL ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	TEMPERATURE, °F FUEL	TEMPERATURE, °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	800	———	362	2.8	72	74	325	1.2	0.0	240	794	1.39	232	202	220	———
2	1500	———	631	5.7	72	72	342	5.3	0.2	188	566	1.72	273	231	268	———
3	1500	15.5	638	9.9	71	69	428	5.5	0.2	158	394	3.05	636	566	610	———
4	1500	30.5	660	14.5	72	68	524	6.0	0.3	188	314	4.26	979	896	938	———
5	1500	45.0	665	19.2	72	68	647	6.1	0.3	228	261	5.45	1296	1221	1264	———
6	1500	60.0	688	25.0	72	69	770	6.5	0.4	240	342	6.65	1582	1455	1511	———
7	1500	75.0	721	30.2	71	71	901	7.2	0.5	186	520	7.65	1822	1618	1686	———
8	1500	90.0	766	36.4	71	72	1027	8.2	0.6	196	887	8.65	2063	1898	1953	———
9	1500	105.0	779	41.7	73	73	1153	8.9	0.6	132	2379	9.42	2204	1958	1985	———
10	1500	120.0	793	48.0	72	74	1294	10.1	0.9	56	4917	10.14	2088	1859	1912	———
11	800	———	352	2.5	72	78	332	1.0	0.0	248	823	1.33	233	211	246	———
12	2200	149.0	1349	60.7	72	72	1203	28.5	1.9	122	714	8.11	1691	1609	1636	———
13	2200	130.0	1268	52.5	72	76	1116	25.0	1.8	150	398	7.72	1680	1535	1590	———
14	2200	111.0	1212	46.0	73	76	1039	23.0	1.5	148	305	6.98	1430	1353	1367	———
15	2200	91.7	1145	39.3	73	77	956	20.4	1.3	148	271	6.38	1233	1140	1154	———
16	2200	74.1	1109	33.7	73	76	877	19.0	1.1	156	260	5.72	1023	966	980	———
17	2200	55.7	1040	27.2	73	76	783	16.5	0.9	160	238	4.98	843	794	799	———
18	2200	36.7	994	21.6	73	77	689	15.0	0.8	170	252	4.18	640	607	626	———
19	2200	18.3	941	15.7	73	76	571	13.2	0.6	156	267	3.26	443	527	546	———
20	2200	———	895	10.9	73	77	482	12.4	0.5	172	346	2.25	261	241	267	———
21	800	———	351	2.3	73	77	291	1.1	0.0	300	890	1.33	191	171	223	———

ENGINE ALLIS-CHALMERS 3500 DATE 11/28/72 WET BULB TEMP., °F 56

RUN 1 BAROMETER, in Hg 29.50 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	800	—	355	2.9	72	76	312	1.3	0.0	288	933	1.33	182	159	209	—
2	1500	—	631	5.9	72	74	339	5.5	0.2	240	620	1.73	253	205	252	—
3	1500	15.0	644	9.9	72	72	431	5.6	0.2	198	445	2.86	564	492	549	—
4	1500	30.0	662	14.8	71	70	539	6.0	0.3	214	340	4.12	896	804	856	—
5	1500	45.0	673	19.8	72	70	658	6.2	0.3	254	274	5.33	1202	1057	1142	—
6	1500	60.0	706	25.0	72	70	779	6.8	0.3	256	319	6.53	1494	1293	1335	—
7	1500	75.0	733	30.7	73	71	914	7.2	0.4	248	534	7.60	1706	1486	1554	—
8	1500	90.0	773	36.6	72	72	1031	8.2	0.5	220	327	8.46	1916	1689	1743	—
9	1500	105.0	816	43.0	73	74	1155	9.2	0.7	114	2430	9.38	2070	1803	1870	—
10	1500	119.0	843	49.7	73	75	1296	10.6	0.8	62	4300	9.90	2009	1695	1749	—
11	800	—	344	2.6	73	77	422	1.1	0.0	192	689	1.33	285	244	270	—
12	2200	151.0	1390	61.1	73	73	1182	29.5	1.9	142	680	7.99	1621	1383	1493	—
13	2200	132.0	1366	54.6	73	76	1123	27.4	1.7	152	436	7.60	1552	1375	1417	—
14	2200	114.0	1285	47.5	73	77	1048	24.9	1.5	160	294	6.94	1347	1206	1247	—
15	2200	94.6	1196	41.0	73	77	967	22.0	1.3	162	247	6.40	1188	1059	1087	—
16	2200	75.5	1138	34.9	74	77	885	20.8	1.0	158	235	5.68	958	871	885	—
17	2200	56.5	1079	28.6	74	77	793	18.0	0.9	172	226	4.88	772	711	720	—
18	2200	38.1	1022	22.4	74	78	698	16.0	0.7	184	238	4.15	611	537	560	—
19	2200	19.1	972	16.5	72	78	591	14.3	0.6	178	253	3.30	427	380	399	—
20	2200	—	937	11.6	72	78	495	13.2	0.5	186	292	2.23	248	218	244	—
21	800	—	344	2.6	73	79	280	1.2	0.0	320	824	1.22	186	151	202	—

ENGINE ALLIS-CHALMERS 3500 DATE 11/30/72 WET BULB TEMP., °F 52

RUN 2 BAROMETER, in Hg 29.46 DRY BULB TEMP., °F 69

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	800	—	343	2.6	73	74	253	1.4	0.0	272	836	1.29	192	220	241	—
2	1500	—	624	5.7	73	74	317	5.4	0.0	224	608	1.53	212	216	252	—
3	1500	15.0	643	9.8	74	74	416	5.5	0.2	180	432	2.79	527	525	573	—
4	1500	30.0	672	14.6	73	73	524	5.9	0.2	196	340	3.98	799	785	842	—
5	1500	45.0	673	19.4	72	74	644	6.0	0.2	234	286	5.18	1090	1056	1099	—
6	1500	60.0	706	25.1	72	75	775	7.1	0.3	232	307	6.39	1319	1225	1281	—
7	1500	75.0	718	30.5	73	77	909	7.5	0.5	224	497	7.46	1570	1486	1513	—
8	1500	90.0	778	36.4	73	78	1025	8.3	0.5	206	789	8.39	1831	1662	1703	—
9	1500	105.0	796	42.5	74	77	1153	9.8	0.6	142	2177	9.25	1982	1845	1872	—
10	1500	118.0	816	49.9	74	79	1300	10.4	0.8	68	4522	9.95	1916	1705	1732	—
11	800	—	332	2.6	73	83	421	1.0	0.0	212	557	1.19	306	253	258	—
12	2200	150.0	1389	60.5	73	77	1187	29.0	1.9	128	642	7.99	1543	1395	1423	—
13	2200	132.0	1337	54.5	74	79	1129	27.0	1.7	146	387	7.59	1494	1360	1388	—
14	2200	114.0	1282	48.0	75	81	1064	24.8	1.5	152	246	6.79	1313	1178	1206	—
15	2200	94.6	1198	41.5	74	80	973	22.3	1.3	150	212	6.27	1127	1019	1047	—
16	2200	75.5	1130	34.5	74	81	886	19.9	1.0	128	213	5.52	924	856	866	—
17	2200	56.5	1078	28.2	72	81	797	18.0	0.8	160	203	4.86	765	703	707	—
18	2200	38.1	1015	22.0	73	81	701	16.0	0.7	178	217	4.06	592	523	537	—
19	2200	19.1	977	16.2	74	81	598	14.1	0.6	170	231	3.12	432	379	394	—
20	2200	—	943	11.5	74	81	501	13.0	0.5	178	271	2.19	251	212	247	—
21	800	—	343	2.4	74	82	293	1.2	0.0	300	769	1.19	191			—

ENGINE ALLIS-CHALMERS 3500 DATE 11/28/72 WET BULB TEMP., °F 54

RUN 3 BAROMETER, in Hg 29.47 DRY BULB TEMP., °F 70

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F: INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS: INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	800	—	344	2.6	73	87	354	1.3	0.0	268	459	1.56	201	188	223	—
2	1500	—	624	5.4	74	84	350	5.4	0.1	224	645	1.72	252	216	262	—
3	1500	15.0	642	9.6	74	81	440	5.8	0.1	186	467	2.83	569	529	591	—
4	1500	29.5	650	14.0	71	79	534	5.9	0.2	202	360	4.08	886	856	913	—
5	1500	44.0	672	18.8	73	79	650	6.0	0.3	240	298	5.44	1213	1151	1207	—
6	1500	59.0	706	24.6	73	80	773	6.9	0.4	254	353	6.49	1449	1397	1452	—
7	1500	74.0	722	29.8	72	82	902	7.5	0.5	240	544	7.65	1681	1577	1645	—
8	1500	89.0	758	35.4	72	83	1019	8.0	0.6	230	925	8.58	1887	1789	1844	—
9	1500	104.0	786	41.5	74	84	1143	9.0	0.7	156	2274	9.43	2065	1893	1960	—
10	1500	118.0	832	49.5	75	85	1288	10.1	0.8	92	4570	10.00	1978	1834	1874	—
11	800	—	332	2.4	73	88	425	1.0	0.0	220	661	1.33	275	254	293	—
12	2200	149.0	1388	60.3	74	85	1185	29.0	1.9	160	677	8.11	1633	1527	1595	—
13	2200	131.0	1337	54.0	74	86	1129	27.5	1.8	168	410	7.72	1546	1467	1508	—
14	2200	111.0	1283	46.9	75	87	1050	24.3	1.5	172	269	6.98	1360	1326	1368	—
15	2200	92.4	1199	40.4	71	87	962	22.0	1.3	174	223	6.52	1184	1139	1167	—
16	2200	74.1	1132	34.0	73	87	884	19.8	1.1	176	225	5.78	979	952	980	—
17	2200	55.7	1069	27.9	74	87	799	17.5	0.9	184	215	5.05	804	772	790	—
18	2200	36.7	1029	22.1	71	87	699	16.0	0.7	200	229	4.19	617	616	617	—
19	2200	18.3	967	16.1	73	86	591	14.5	0.5	190	242	3.26	431	412	436	—
20	2200	—	934	11.4	75	87	499	13.0	0.4	192	286	2.27	253	228	258	—
21	800	—	343	2.4	75	88	284	1.2	0.0	340	823	1.26	202	167	217	—

ENGINE ALLIS-CHALMERS 3500 DATE 11/28/72 WET BULB TEMP, °F 55

RUN 4 BAROMETER, in Hg 29.44 DRY BULB TEMP., °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	800	—	355	2.0	74	77	342	1.0	0.3	292	849	1.33	201	175	216	—
2	1500	—	636	5.5	74	76	339	5.0	0.2	224	540	1.72	274	230	277	—
3	1500	14.0	649	9.5	72	74	420	5.0	0.2	184	368	2.92	599	568	625	—
4	1500	30.0	655	14.0	73	73	522	6.0	0.3	204	277	4.12	938	898	941	—
5	1500	45.5	677	19.2	74	74	643	6.5	0.4	246	226	5.45	1231	1222	1279	—
6	1500	60.0	727	24.4	72	75	780	7.0	0.4	254	282	6.66	1510	1484	1526	—
7	1500	75.0	737	30.6	73	77	905	8.0	0.5	240	707	7.65	1700	1645	1672	—
8	1500	90.5	767	36.0	74	77	1024	7.5	0.5	208	773	8.65	1952	1871	1953	—
9	1500	104.0	811	42.5	74	79	1159	9.0	0.8	132	2024	9.44	2090	1962	2002	—
10	1500	120.0	850	46.5	74	80	1299	10.0	0.8	54	4167	10.15	2045	1900	1927	—
11	800	—	343	2.5	73	82	465	1.0	0.2	264	767	1.33	242	763	792	—
12	2200	146.0	1353	59.5	74	77	1175	28.0	1.9	142	518	7.98	1617	1571	1598	—
13	2200	130.0	1310	53.0	73	81	1121	26.0	1.8	152	362	7.72	1564	1481	1508	—
14	2200	111.0	1255	46.9	73	81	1051	24.0	1.5	152	233	6.98	1360	1326	1354	—
15	2200	92.4	1195	40.3	74	82	972	21.5	1.3	156	211	6.45	1201	1126	1154	—
16	2200	74.1	1140	34.4	71	81	882	19.5	1.1	160	201	5.73	980	939	953	—
17	2200	55.7	1070	27.7	72	82	796	17.0	0.8	168	190	4.92	804	782	791	—
18	2200	36.7	1011	21.5	73	82	707	15.0	0.7	182	204	4.12	604	589	599	—
19	2200	18.3	957	15.5	70	81	521	9.0	0.5	178	219	3.20	444	422	432	—
20	2200	—	925	11.0	70	81	497	7.5	0.4	196	271	2.26	262	233	264	—
21	800	—	355	2.5	73	82	304	1.0	0.2	332	851	1.33	192	164	218	—

ENGINE ALLIS-CHALMERS 3500 DATE 11/29/72 WET BULB TEMP, °F 55

RUN 5 BAROMETER, in Hg 29.40 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	800	———	366	2.6	72	68	316	1.0	0.0	268	863	1.40	182	179	223	———
2	1500	———	636	5.5	73	69	325	5.0	0.2	216	619	1.72	232	210	246	———
3	1500	15.5	649	10.0	73	68	422	6.0	0.3	178	445	2.86	527	482	530	———
4	1500	30.0	666	14.5	73	68	531	6.0	0.3	198	339	4.19	894	816	868	———
5	1500	45.0	683	19.5	73	69	651	6.0	0.4	236	285	5.52	1197	1081	1123	———
6	1500	60.0	694	24.4	72	69	771	6.5	0.4	236	342	6.65	1471	1331	1358	———
7	1500	74.5	722	30.0	72	71	905	7.0	0.6	222	521	7.73	1683	1510	1537	———
8	1500	90.0	757	35.5	72	72	1020	8.0	0.7	196	862	8.66	1931	1697	1751	———
9	1500	105.0	820	42.9	73	74	1156	9.5	0.8	124	2506	9.51	2042	1799	1853	———
10	1500	119.0	850	51.2	74	74	1302	10.5	1.0	50	4454	10.14	1955	1741	1768	———
11	800	———	332	3.0	74	80	349	0.5	0.0	248	823	1.33	243	197	211	———
12	2200	143.0	138[illegible]	57.0	73	74	115[illegible]	23.0	1.9	128	617	8.13	1579	1394	1421	———
13	2200	130.0	1336	53.5	74	77	1123	[illegible]	1.9	144	411	7.73	[illegible]8	1373	1400	———
14	2200	111.0	1253	46.4	74	77	1041	28.5	1.7	146	293	7.05	[illegible]	1201	1230	———
15	2200	92.4	1178	39.9	74	77	961	21.0	1.4	148	270	6.52	1153	1028	1042	———
16	2200	74.8	1136	34.2	74	78	884	19.5	1.2	152	248	5.79	950	863	873	———
17	2200	55.7	1073	27.5	71	78	786	17.0	1.0	158	238	5.05	776	696	706	———
18	2200	36.7	1016	21.4	71	78	680	15.0	0.8	172	[illegible]	4.19	604	532	542	———
19	2200	19.1	967	15.9	72	77	530	14.0	0.5	166	[illegible]	3.26	421	364	384	———
20	2200	———	926	11.0	73	[illegible]	492	[illegible]	[illegible]	178	[illegible]	2.32	251	[illegible]11	235	———
21	800	———	355	2.5	73	74	[illegible]	[illegible]	0.0	316	877	1.33	182	141	191	———

ENGINE ALLIS-CHALMERS 3500 DATE 11/2[illegible]/72 WET BULB TEMP, °F 54

RUN 6 BAROMETER, in Hg 29.44 DRY BULB TEMP, °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	800	—	—	2.6	74	81	—	1.0	—	240	755	1.26	233	220	241	—
2	1700	—	—	6.7	74	78	—	7.0	—	182	450	1.72	263	231	266	—
3	1700	34.0	—	16.5	72	76	—	8.2	—	174	277	4.12	810	759	797	—
4	1700	68.0	—	27.6	72	75	—	9.5	—	188	271	6.39	1352	1251	1307	—
5	1700	102.0	—	39.6	73	76	—	11.3	—	176	626	8.38	1871	1714	1769	—
6	1700	135.0	—	53.7	74	78	—	14.0	—	56	2917	9.89	1984	1787	1840	—
7	800	—	—	2.4	74	82	—	1.0	—	100	636	1.26	295	284	352	—
8	2000	148.0	—	58.5	73	78	—	22.8	—	104	1344	8.78	1737	1597	1651	—
9	2000	111.0	—	44.5	74	81	—	18.5	—	132	351	7.38	1589	1472	1513	—
10	2000	74.0	—	31.7	74	82	—	15.2	—	136	235	5.98	1158	1060	1088	—
11	2000	36.7	—	19.4	72	83	—	12.4	—	150	229	4.06	705	656	665	—
12	2000	—	—	9.0	73	83	—	10.2	—	164	347	1.99	262	240	251	—
13	800	—	—	2.4	74	84	—	1.1	—	254	795	1.26	202	184	219	—

ENGINE ALLIS-CHALMERS 3500　　DATE 11/30/72　　WET BULB TEMP., °F 57

MAPPING RUN M-1　　BAROMETER, in Hg 29.37　　DRY BULB TEMP., °F 75

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	800	—	—	2.5	74	81	—	1.0	—	292	850	1.19	192	158	202	—
2	1700	—	—	6.8	74	78	—	7.0	—	232	488	1.72	252	221	260	—
3	1700	34.0	—	16.7	72	76	—	8.2	—	210	277	4.18	823	749	777	—
4	1700	68.0	—	28.2	72	75	—	9.5	—	204	283	6.39	1352	1251	1279	—
5	1700	102.0	—	40.2	73	76	—	11.3	—	192	664	8.25	1854	1677	1718	—
6	1700	134.0	—	53.2	74	78	—	14.0	—	76	2996	9.69	1923	1737	1778	—
7	800	—	—	2.4	74	82	—	1.0	—	196	642	1.27	320	264	284	—
8	2000	148.0	—	58.6	73	78	—	22.8	—	108	1389	8.72	1721	1532	1573	—
9	2000	111.0	—	44.5	74	81	—	18.5	—	140	351	7.38	1570	1431	1458	—
10	2000	74.0	—	31.7	74	82	—	15.2	—	142	236	5.91	1175	1061	1075	—
11	2000	37.3	—	19.8	72	83	—	12.4	—	156	229	4.12	717	655	660	—
12	2000	—	—	9.0	73	83	—	10.2	—	166	234	1.99	273	236	251	—
13	800	—	—	2.4	74	84	—	1.1	—	260	850	1.19	192	173	202	—

ENGINE ALLIS-CHALMERS 3500 DATE 11/30/72 WET BULB TEMP, °F 57

MAPPING RUN Ai-2 BAROMETER, in Hg 29.37 DRY BULB TEMP, °F 75

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	EXH. POST-TURBO	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppm C	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	650	———	456	3.4	85	80	274	245	1.5	0.0	26	249	1.26	56	51	48	18.1
2	1400	———	917	7.8	79	80	288	266	2.5	0.1	24	275	1.53	64	63	59	17.8
3	1400	15.9	956	12.2	77	78	352	323	2.5	0.1	6	155	2.45	150	144	139	16.3
4	1400	31.3	974	16.0	77	78	412	384	4.0	0.2	4	102	3.31	279	263	255	15.3
5	1400	47.6	991	20.4	79	77	508	454	4.0	0.3	8	76	4.24	438	406	406	13.7
6	1400	63.0	989	24.2	81	78	593	535	4.0	0.4	8	50	5.17	548	533	533	12.4
7	1400	79.3	1005	30.5	82	78	695	633	4.0	0.5	10	74	6.10	615	593	593	10.7
8	1400	94.3	1020	35.2	85	77	795	736	4.0	0.6	12	86	6.90	610	588	588	9.5
9	1400	110.6	1047	40.8	91	78	898	863	4.0	0.7	12	73	7.56	570	556	556	8.5
10	1400	127.9	1061	45.6	94	80	1017	1007	4.0	0.8	10	97	8.49	553	533	533	7.2
11	650	———	453	3.5	92	80	454	411	1.5	0.0	12	222	1.46	93	87	85	18.0
12	1900	146.3	1539	58.5	82	76	935	906	7.0	1.4	6	98	7.63	534	529	510	8.5
13	1900	127.9	1430	50.6	94	78	959	866	7.0	1.3	6	73	7.16	573	545	527	9.3
14	1900	108.9	1356	44.0	95	78	902	788	5.5	1.1	4	74	6.50	565	554	554	10.3
15	1900	91.8	1330	38.6	95	80	805	689	5.5	1.0	8	25	5.84	521	502	488	11.3
16	1900	72.2	1252	31.2	94	80	733	618	5.5	0.9	6	88	5.10	468	450	440	12.4
17	1900	53.8	1255	26.8	92	80	651	537	5.5	0.8	4	89	4.24	339	331	321	13.5
18	1900	36.7	1171	23.2	91	78	556	470	4.0	0.7	4	114	3.64	247	234	234	14.6
19	1900	18.4	1230	17.0	89	77	478	414	4.0	0.6	4	141	2.65	150	141	141	15.9
20	1900	———	1234	13.2	86	77	400	356	4.0	0.5	20	234	1.98	83	84	84	16.9
21	650	———	456	3.2	85	78	265	232	1.5	0.0	76	302	1.19	56	44	41	18.1

ENGINE CATERPILLAR D6C   DATE 2/1/72   WET BULB TEMP., °F 60

RUN 1   BAROMETER, in Hg 29.20   DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	EXH. POST-TURBO	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppm C	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	640	——	467	3.0	81	90	252	222	1.5	0.0	72	276	1.26	46	73	34	——
2	1400	——	958	7.5	78	90	285	270	6.5	0.2	64	275	1.79	64	80	50	——
3	1400	15.9	959	11.5	77	92	346	324	6.7	0.2	66	168	2.59	160	153	125	——
4	1400	31.7	959	15.8	77	96	417	384	6.7	0.3	58	90	3.52	279	262	238	——
5	1400	47.6	957	20.0	79	100	508	461	6.9	0.4	38	63	4.18	417	403	384	——
6	1400	63.5	975	24.4	79	102	594	558	7.0	0.4	36	63	5.25	598	539	506	——
7	1400	79.8	991	29.8	81	104	686	654	7.3	0.5	36	74	5.63	640	589	557	——
8	1400	94.7	1023	34.2	84	108	791	764	7.5	0.6	32	86	6.97	647	570	556	——
9	1400	111.1	1055	41.6	86	108	899	876	8.2	0.7	30	73	7.78	605	547	529	——
10	1400	130.2	1116	50.0	89	108	1033	1028	9.2	0.9	28	108	9.10	550	530	503	——
11	640	——	431	3.0	93	102	480	436	1.5	0.0	82	222	1.33	64	68	43	——
12	1900	152.0	1505	60.0	85	110	995	970	15.7	1.5	26	110	7.64	606	566	557	——
13	1900	131.7	1408	51.6	92	108	1008	907	14.2	1.4	24	98	7.11	634	560	560	——
14	1900	114.0	1338	45.5	92	108	929	827	13.0	1.2	26	111	6.58	601	545	527	——
15	1900	95.0	1285	39.0	92	106	843	737	12.0	1.0	30	125	5.91	581	516	493	——
16	1900	76.0	1259	33.0	91	104	746	645	11.5	0.9	34	138	4.98	481	432	423	——
17	1900	57.0	1235	27.2	88	102	650	559	11.2	0.8	34	139	4.31	361	331	312	——
18	1900	37.4	1230	21.6	87	102	553	483	11.0	0.7	36	166	3.52	269	229	210	——
19	1900	18.4	1224	16.5	85	102	461	409	11.0	0.6	40	219	2.66	169	147	124	——
20	1900	——	1242	12.5	82	102	388	353	11.0	0.5	76	326	2.05	111	95	60	——
21	640	——	435	3.0	81	104	250	218	1.5	0.0	114	355	1.26	64	62	28	——

ENGINE CATERPILLAR D6C — DATE 2/10/72 — WET BULB TEMP., °F 59

RUN 5 — BAROMETER, in Hg 29.34 — DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	EXH. POST-TURBO	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppm C	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	640	———	475	2.8	79	98	289	254	1.5	0.0	84	355	1.12	37	66	30	———
2	1400	———	957	7.4	79	96	293	276	6.5	0.2	70	314	1.65	64	85	48	———
3	1400	16.3	957	11.4	79	102	350	329	6.7	0.2	36	220	2.18	151	159	147	———
4	1400	32.7	956	16.2	80	106	430	397	6.8	0.3	30	90	3.11	300	268	249	———
5	1400	49.5	975	21.0	79	108	521	474	7.0	0.3	28	63	4.05	474	426	388	———
6	1400	65.3	992	24.6	80	110	613	572	7.0	0.4	26	75	5.11	634	553	515	———
7	1400	81.7	1019	31.0	81	110	714	671	7.5	0.5	24	74	6.04	677	584	566	———
8	1400	98.5	1039	38.2	85	110	836	794	8.0	0.6	22	62	6.96	659	560	551	———
9	1400	115.7	1085	44.0	88	106	941	909	8.5	0.7	20	85	7.89	616	546	537	———
10	1400	130.7	1145	50.2	90	102	1053	1030	9.5	0.9	14	97	8.57	623	551	542	———
11	640	———	441	3.0	88	98	388	347	1.5	0.0	84	276	1.19	56	65	45	———
12	1900	149.5	1525	59.5	79	110	985	953	15.5	1.6	24	109	7.89	568	546	491	———
13	1900	133.0	1434	52.5	85	110	1010	907	14.5	1.4	24	110	7.36	584	567	540	———
14	1900	113.4	1367	45.4	89	106	924	820	13.0	1.2	30	74	6.77	611	543	534	———
15	1900	95.6	1302	39.2	89	104	841	734	12.2	1.0	30	111	6.17	555	509	500	———
16	1900	75.4	1268	32.6	88	102	751	648	11.5	0.9	36	112	5.37	467	420	411	———
17	1900	57.0	1252	27.5	85	100	656	558	11.5	0.8	34	113	4.57	382	330	320	———
18	1900	38.0	1243	22.0	81	100	557	485	11.0	0.7	36	127	3.71	237	228	208	———
19	1900	19.0	1244	17.0	80	100	470	412	11.0	0.6	40	167	2.85	129	147	124	———
20	1900	———	1259	12.5	79	100	402	361	11.0	0.6	64	260	2.18	102	94	60	———
21	640	———	467	2.9	80	102	248	216	1.5	0.0	106	314	1.39	46	58	27	———

ENGINE CATERPILLAR D6C DATE 2/10/72 WET BULB TEMP., °F 61

RUN 6 BAROMETER, in Hg 29.32 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	440	—	555	2.5	71	140	221	0.4	0.1	96	222	1.32	191	214	234	—
2	1600	—	2213	12.0	72	141	232	6.6	1.6	96	160	1.32	170	185	212	—
3	1600	22.9	2213	18.0	72	147	300	7.0	2.0	98	85	1.92	336	411	445	—
4	1600	42.7	2213	23.5	72	149	355	7.0	2.0	100	48	2.44	527	631	674	—
5	1600	64.0	2179	28.5	71	150	423	6.6	2.8	104	36	2.91	764	881	929	—
6	1600	86.4	2175	38.0	73	150	492	6.6	2.5	106	24	3.58	1074	1142	1200	—
7	1600	108.3	2206	44.0	75	150	577	7.0	2.5	116	24	4.30	1359	1458	1600	—
8	1600	128.5	2260	53.0	75	150	670	7.0	2.8	122	47	5.03	1606	1759	1914	—
9	1600	149.9	2173	62.0	74	150	751	7.0	3.1	146	393	5.90	1728	1812	1965	—
10	1600	168.5	2173	70.5	74	149	823	7.0	3.4	158	2113	6.42	1598	1646	1756	—
11	440	—	526	2.5	72	148	895	0.5	0.1	112	160	1.12	295	278	288	—
12	2100	205.8	2875	87.0	74	146	826	11.5	4.9	146	953	6.03	1765	1877	2016	—
13	2100	182.0	2869	76.5	76	151	785	11.0	4.9	138	93	5.43	1778	1905	2073	—
14	2100	154.7	2785	70.0	71	156	701	10.5	4.5	132	36	4.71	1651	1778	1906	—
15	2100	128.8	2939	53.0	75	159	626	11.0	4.4	126	47	3.97	1347	1465	1536	—
16	2100	102.2	2759	44.0	75	159	844	11.0	3.9	124	48	3.38	1124	1173	1245	—
17	2100	77.0	2768	39.0	72	161	471	11.0	3.6	124	48	2.85	889	921	949	—
18	2100	52.5	2805	32.0	74	161	415	11.0	3.5	122	61	2.32	690	704	733	—
19	2100	24.5	2942	23.0	74	161	349	11.0	3.3	126	73	1.72	472	456	476	—
20	2100	—	2945	17.0	73	162	299	11.0	3.0	132	97	1.32	294	273	286	—
21	440	—	575	3.0	73	159	224	0.5	0.1	112	185	1.00	264	246	270	—

ENGINE DETROIT DIESEL 6V-71 DATE 10/24/72 WET BULB TEMP, °F 58

RUN 3 BAROMETER, in Hg 29.36 DRY BULB TEMP., °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	440	—	560	2.5	74	114	333	0.5	0.1	88	210	1.00	264	235	256	—
2	1600	—	2174	10.5	73	119	252	6.5	1.7	94	172	1.00	212	180	202	—
3	1600	21.9	2194	16.0	72	124	296	7.0	1.9	84	110	1.53	381	394	413	—
4	1600	42.7	2172	23.0	74	125	353	7.0	2.0	84	73	2.05	578	615	649	—
5	1600	65.1	2178	30.0	71	126	423	7.0	2.1	88	48	2.72	779	850	897	—
6	1600	85.9	2153	37.0	74	127	492	6.5	2.5	94	48	3.31	1031	1103	1175	—
7	1600	108.3	2158	44.0	72	127	576	6.5	2.5	100	47	3.98	1280	1409	1523	—
8	1600	129.6	2158	52.5	72	127	664	7.0	2.8	116	83	4.78	1536	1694	1878	—
9	1600	149.9	2150	61.5	76	127	749	6.5	3.0	138	468	5.51	1696	1778	1946	—
10	1600	170.7	2176	72.0	72	127	832	6.5	3.4	132	2447	6.09	1566	1555	1680	—
11	440	—	553	2.5	75	127	430	0.5	0.1	108	224	0.79	274	227	250	—
12	2100	208.6	2958	87.5	75	124	824	11.5	5.0	142	616	5.98	1709	1743	1882	—
13	2100	182.7	2943	78.0	77	131	800	11.5	5.0	132	153	5.37	1718	1808	1962	—
14	2100	154.7	2842	66.0	74	134	721	10.0	4.4	130	58	445	1541	1614	1770	—
15	2100	129.5	2831	56.0	74	135	624	10.5	4.1	130	48	3.79	1334	1384	1484	—
16	2100	105.0	2996	53.5	73	136	564	10.0	4.3	130	59	3.25	1110	1118	1190	—
17	2100	77.0	2830	39.5	74	137	488	11.0	3.8	128	60	2.52	865	867	916	—
18	2100	51.1	2905	31.5	73	137	423	11.5	3.5	128	60	1.99	666	654	697	—
19	2100	25.2	2966	26.0	74	137	359	11.5	3.5	134	73	1.46	485	443	467	—
20	2100	—	2957	19.0	75	137	310	12.0	3.3	138	99	1.00	306	259	298	—
21	440	—	576	3.0	72	135	234	0.5	0.1	116	186	0.60	265	221	257	—

ENGINE DETROIT DIESEL 6V-71 DATE 10/24/72 WET BULB TEMP, °F 58

RUN 4 BAROMETER, in Hg 29.33 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	440	———	547	2.4	73	99	370	0.5	0.1	76	210	0.93	242	214	232	———
2	1600	———	2213	11.2	72	107	252	7.0	1.9	80	147	0.99	212	179	205	———
3	1600	22.4	2228	18.1	73	116	290	7.2	2.0	72	97	1.52	403	393	418	———
4	1600	43.2	2195	24.2	72	119	351	7.0	2.0	74	61	2.12	602	613	652	———
5	1600	64.0	2251	31.2	71	121	411	6.8	2.3	74	48	2.71	819	844	897	———
6	1600	86.4	2177	38.5	72	122	487	6.8	2.3	78	48	3.31	1075	1086	1172	———
7	1600	108.3	2147	45.0	73	122	559	6.6	2.5	82	47	3.97	1329	1421	1534	———
8	1600	128.5	2153	51.4	70	123	650	6.6	2.8	92	83	4.76	1568	1646	1787	———
9	1600	150.9	2156	63.0	73	123	727	6.6	3.0	108	491	5.62	1748	1742	1881	———
10	1600	170.1	2164	72.7	74	123	826	6.9	3.4	104	2501	6.28	1617	1549	1632	———
11	440	———	541	3.2	72	123	301	0.5	0.0	80	236	0.72	253	229	252	———
12	2100	208.6	2834	88.5	71	116	345	11.5	4.9	108	666	5.96	1745	1780	1919	———
13	2100	182.7	2831	78.5	75	124	802	11.5	5.2	98	153	5.23	1758	1849	1989	———
14	2100	155.4	2939	66.5	75	129	718	11.0	4.6	98	83	4.50	1631	1666	1821	———
15	2100	130.9	2744	57.0	73	131	628	10.5	4.2	100	71	3.78	1402	1452	1552	———
16	2100	103.6	2734	47.7	74	131	576	10.9	3.9	100	72	3.10	1109	1146	1203	———
17	2100	77.0	2795	39.2	70	132	490	11.0	3.8	102	72	2.51	862	879	932	———
18	2100	51.1	2777	32.5	74	132	425	11.1	3.5	102	73	1.92	666	658	692	———
19	2100	25.2	2880	24.1	72	133	351	11.0	3.3	104	86	1.39	461	437	476	———
20	2100	———	2924	18.9	71	133	297	11.8	3.3	110	110	1.00	295	268	298	———
21	440	———	568	3.5	73	132	174	0.5	0.0	94	223	0.66	254	235	267	———

ENGINE DETROIT DIESEL 6V-71　　DATE 12/25/72　　WET BULB TEMP., °F 60

RUN 5　　BAROMETER, in Hg 29.36　　DRY BULB TEMP., °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	440	—	—	2.6	74	111	—	0.7	0.1	70	209	1.04	190	226	264	—
2	1200	—	—	6.3	74	111	—	3.5	0.9	80	260	0.928	142	152	180	—
3	1200	24.0	—	18.5	73	119	—	4.0	1.0	84	72	2.25	503	617	656	—
4	1200	49.2	—	29.3	72	120	—	4.0	1.2	90	36	3.64	997	1111	1211	—
5	1200	73.2	—	41.5	70	120	—	4.0	1.4	104	118	4.96	1455	1573	1714	—
6	1200	98.1	—	59.0	74	120	—	3.8	1.7	106	5095	6.53	1372	1279	1334	—
7	440	—	—	2.6	75	120	—	0.7	0.1	83	333	1.78	272	221	242	—
8	1800	140.0	—	80.6	72	118	—	9.0	4.0	106	1862	6.15	1526	1538	1926	—
9	1800	105.0	—	61.9	73	124	—	8.7	3.7	102	82	4.96	1585	1672	1812	—
10	1800	69.3	—	41.6	72	128	—	8.5	3.1	100	24	3.51	1043	1084	1156	—
11	1800	34.2	—	27.0	73	130	—	8.5	2.6	102	37	2.11	614	613	647	—
12	1800	—	—	13.9	71	130	—	8.7	2.3	96	110	0.996	242	196	229	—
13	440	—	—	2.9	72	129	—	0.5	0.1	82	210	0.860	233	196	221	—

ENGINE DETROIT DIESEL 6V-71 DATE 10/23/72 WET BULB TEMP., °F 60

MAPPING RUN M-1 BAROMETER, in Hg 29.30 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	440	—	—	2.7	72	120	—	0.5	0.1	98	222	1.12	161	179	210	—
2	1200	—	—	7.1	70	117	—	3.6	0.9	90	235	1.12	121	152	181	—
3	1200	24.3	—	18.3	72	122	—	4.0	1.0	88	85	2.31	551	611	655	—
4	1200	49.5	—	30.2	70	122	—	4.0	1.2	96	47	3.78	996	1068	1153	—
5	1200	73.8	—	41.8	74	122	—	4.0	1.4	112	153	5.29	1449	1567	1707	—
6	1200	96.8	—	59.0	74	122	—	3.9	1.7	112	5022	6.65	1284	1249	1331	—
7	440	—	—	2.6	72	122	—	0.5	0.1	100	210	1.05	212	214	237	—
8	1800	140.0	—	80.5	71	124	—	8.6	2.9	118	1961	6.27	1485	1464	1547	—
9	1800	104.0	—	58.4	74	125	—	8.4	3.6	108	70	4.77	1514	1563	1690	—
10	1800	69.8	—	41.8	72	129	—	8.2	2.1	108	48	3.51	1027	1056	1113	—
11	1800	34.6	—	26.8	73	131	—	8.4	2.7	110	61	2.18	576	593	632	—
12	1800	—	—	13.7	70	131	—	8.8	2.4	122	123	1.12	181	191	219	—
13	440	—	—	2.8	70	127	—	0.5	0.1	116	197	1.00	191	217	2357	—

ENGINE DETROIT DIESEL 6V-71   DATE 10/23/72   WET BULB TEMP., °F 60

MAPPING RUN M-2   BAROMETER, in Hg 29.26   DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	—	—	1.6	92	90	373	1.9	0.0	450	269	1.51	197	116	165	18.8
2	1800	—	—	5.4	89	90	280	11.2	0.5	665	368	1.69	102	54	98	18.6
3	1800	12.6	—	3.9	88	91	347	10.9	0.6	610	341	2.65	177	136	192	17.0
4	1800	24.0	—	12.0	89	92	417	10.9	0.7	580	309	3.50	272	240	292	15.1
5	1800	36.0	—	15.7	89	95	498	11.1	0.7	600	295	4.41	373	345	401	13.8
6	1800	48.0	—	19.7	89	97	586	10.8	0.8	640	347	5.44	491	498	544	12.2
7	1800	60.0	—	23.8	89	98	625	10.7	1.0	690	489	6.41	707	712	749	10.5
8	1800	72.0	—	27.8	90	99	811	10.5	1.2	850	1028	7.66	872	900	923	8.6
9	1800	84.0	—	32.5	89	100	931	10.9	1.2	1040	2536	8.61	982	1045	1077	6.7
10	1800	96.0	—	39.0	90	101	1062	9.7	1.2	820	7508	9.48	1032	1116	1138	4.5
11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	2500	106.	—	43.8	88	102	933	19.7	1.4	1080	1819	8.37	1184	1338	1405	6.7
13	2500	91.7	—	38.2	93	105	924	19.8	1.3	825	915	7.51	1073	1171	1239	8.1
14	2500	79.2	—	33.1	88	106	838	19.7	1.2	740	501	6.55	875	958	1003	9.6
15	2500	65.0	—	28.5	87	98	750	19.9	1.0	810	413	5.71	686	736	782	11.2
16	2500	52.5	—	24.7	87	95	677	20.2	0.9	790	371	4.98	509	543	593	12.2
17	2500	40.0	—	21.2	86	99	598	20.4	0.8	770	374	4.29	380	388	448	13.5
18	2500	25.8	—	16.8	87	102	518	20.3	0.7	780	389	3.50	257	249	311	14.7
19	2500	13.3	—	13.2	88	98	442	20.4	0.6	810	403	2.83	160	147	203	15.7
20	2500	—	—	10.0	88	96	378	20.2	0.5	880	406	2.12	86	82	132	16.6
21	700	—	—	1.6	91	95	279	1.9	0.0	630	269	1.51	127	115	178	17.4

ENGINE INTERNATIONAL D407 DATE 5/8/72 WET BULB TEMP., °F 72

RUN 2 BAROMETER, in Hg 29.13 DRY BULB TEMP., °F 80

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	———	——	1.6	89	95	296	1.9	0.0	485	259	1.40	121	108	162	18.9
2	1800	———	——	5.7	86	91	260	11.6	0.2	595	351	1.61	60	53	91	18.7
3	1800	12.0	——	9.0	85	90	333	11.3	0.4	520	336	2.56	134	126	179	17.2
4	1800	23.4	——	11.8	84	91	409	11.0	0.4	505	287	3.46	273	227	288	16.0
5	1800	36.0	——	17.1	84	95	492	11.3	0.3	480	318	4.42	366	341	393	14.2
6	1800	47.4	——	18.8	83	97	598	10.9	0.4	535	337	5.32	469	482	620	12.8
7	1800	60.0	——	22.6	84	97	690	10.7	0.5	560	457	6.42	665	686	746	11.2
8	1800	72.0	——	30.6	84	98	819	11.2	0.7	710	991	7.60	875	892	926	9.0
9	1800	83.4	——	33.1	84	97	972	10.7	0.9	905	2285	8.71	993	1035	1069	7.2
10	1800	96.0	——	37.8	84	96	1038	10.0	0.9	800	6590	9.91	980	1109	1153	4.8
11	700	———	——	1.1	88	94	555	2.1	0.0	540	261	1.47	142	135	154	18.8
12	2500	104.	——	43.4	83	95	909	19.8	1.5	940	1488	8.71	1245	1314	1381	7.3
13	2500	91.7	——	37.4	99	[illegible]	[illegible]	19.7	1.5	715	713	7.77	1095	1128	1173	8.7
14	2500	80.0	——	34.0	99	102	856	19.8	1.4	665	532	7.16	927	943	988	10.0
15	2500	65.8	——	28.7	98	99	799	19.9	1.3	710	379	6.28	718	706	752	11.5
16	2500	52.5	——	24.8	99	95	702	19.9	1.2	705	326	5.38	532	518	564	12.9
17	2500	40.0	——	20.8	98	97	613	20.2	1.1	670	317	4.67	402	383	429	14.0
18	2500	26.7	——	17.0	97	99	531	20.2	0.9	680	320	3.81	207	245	301	15.1
19	2500	13.3	——	13.1	96	97	459	20.0	0.8	690	334	3.06	140	147	204	16.3
20	2500	———	——	9.8	95	95	368	20.2	0.8	720	360	2.24	73	86	144	17.6
21	700	———	——	1.5	95	93	278	1.9	0.0	580	190	1.51	100	106	154	18.6

ENGINE INTERNATIONAL D407 DATE 5/8/72 WET BULB TEMP, °F 68

RUN 3 BAROMETER, in Hg 29.10 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	———	293	1.7	84	90	246	2.1	0.0	465	283	1.41	128	106	160	19.2
2	1800	———	722	5.7	81	90	245	11.4	0.2	605	375	1.56	60	48	87	18.8
3	1800	12.0	728	9.1	80	90	339	11.6	0.4	555	371	2.51	134	124	177	17.5
4	1800	24.0	726	12.3	79	90	408	11.5	0.5	520	322	3.35	252	228	284	16.1
5	1800	36.0	710	15.3	79	90	513	11.0	0.5	510	319	4.24	375	338	385	14.6
6	1800	48.0	715	19.2	79	91	600	11.3	0.6	545	372	5.20	535	493	549	13.0
7	1800	60.0	704	22.6	80	92	679	11.1	0.8	580	482	6.15	703	690	708	11.4
8	1800	72.0	710	27.9	80	92	798	11.3	1.0	710	1010	7.24	909	886	909	9.5
9	1800	84.0	708	33.4	80	93	1016	11.2	1.0	915	2656	8.24	1110	1067	1100	7.2
10	1800	96.0	693	38.2	82	95	1066	10.6	1.0	870	7198	9.28	1192	1181	1214	4.9
11	700	———	293	1.3	87	91	495	1.9	0.0	545	259	1.41	170	155	165	18.6
12	2500	113.	945	46.6	81	95	931	19.9	1.5	1040	2183	8.73	1446	1384	1440	6.3
13	2500	100.	944	40.7	82	98	967	19.7	1.5	860	1130	7.78	1340	1243	1288	8.1
14	2500	85.8	950	34.5	82	100	883	19.9	1.4	700	663	6.87	1118	1027	1061	9.7
15	2500	71.7	956	30.6	84	100	788	20.2	1.3	705	506	6.09	792	810	838	11.1
16	2500	56.7	956	25.1	84	91	697	20.3	1.2	730	418	5.13	576	567	605	12.6
17	2500	42.5	958	21.1	82	90	610	20.2	1.0	700	434	4.31	405	376	423	13.8
18	2500	29.2	961	17.0	81	93	521	20.3	0.9	700	448	3.52	273	246	303	15.1
19	2500	14.2	963	13.5	81	95	454	20.5	0.8	730	476	2.79	168	100	205	16.2
20	2500	———	965	10.1	81	95	394	20.7	0.7	780	480	2.03	93	82	115	17.5
21	700	———	282	1.7	85	91	244	2.9	0.0	575	317	1.41	135	116	174	18.3

ENGINE INTERNATIONAL D407 DATE 5/9/72 WET BULB TEMP, °F 65

RUN 4 BAROMETER, in Hg 29.17 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	———	308	1.4	94	90	491	2.2	0.0	415	248	1.41	149	121	160	19.1
2	1800	———	729	5.6	90	90	322	11.6	0.2	575	328	1.61	73	53	92	18.8
3	1800	11.4	723	8.7	89	90	334	11.4	0.3	545	314	2.56	141	124	158	17.5
4	1800	24.0	721	11.8	88	91	415	11.4	0.4	570	288	3.59	258	227	279	15.8
5	1800	36.0	722	15.8	90	93	502	11.2	0.3	550	296	4.56	388	337	393	14.2
6	1800	48.0	720	19.7	89	95	595	11.8	0.3	560	326	5.47	533	464	519	12.7
7	1800	60.0	724	23.7	91	96	702	11.5	0.5	610	435	6.51	779	688	743	11.0
8	1800	72.0	707	27.7	90	97	819	11.6	0.8	760	967	7.78	913	836	881	9.1
9	1800	84.0	713	33.9	92	97	920	11.5	1.0	980	2819	9.10	1109	1045	1089	6.8
10	1800	96.0	684	38.6	95	99	1071	10.4	0.8	800	7133	10.06	1141	1094	1127	4.5
11	700	———	294	1.1	98	97	532	1.9	0.0	540	257	2.13	134	144	187	17.8
12	2500	108.	949	43.7	90	100	990	19.8	1.2	1050	1837	8.57	1337	1365	1410	7.2
13	2500	94.2	959	38.4	92	104	946	20.3	1.1	830	895	7.62	1222	1199	1244	8.2
14	2500	80.8	945	33.2	92	106	870	20.6	1.0	720	548	6.73	1011	984	1017	9.8
15	2500	66.7	968	29.1	93	109	767	20.2	0.9	760	426	5.95	757	756	784	11.1
16	2500	55.3	966	24.9	93	107	697	20.7	0.8	765	384	5.13	577	558	595	12.4
17	2500	40.0	970	20.3	92	105	619	20.7	0.6	750	375	4.43	435	408	422	13.5
18	2500	26.3	971	17.4	92	105	535	20.8	0.6	725	390	3.64	295	284	302	15.1
19	2500	13.3	976	13.3	92	106	472	20.9	0.6	740	405	2.89	188	186	209	15.7
20	2500	———	969	9.8	91	106	406	20.8	0.6	785	408	2.13	113	106	154	16.9
21	700	———	315	1.4	92	106	294	2.1	0.0	600	282	1.52	142	87	169	17.9

ENGINE INTERNATIONAL D407 DATE 5/9/72 WET BULB TEMP, °F 66

RUN 5 BAROMETER, in Hg 29.12 DRY BULB TEMP., °F 77

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	———	304	1.6	84	90	472	2.0	0.0	464	270	1.41	177	135	179	18.9
2	1800	———	740	5.2	81	90	300	11.6	0.3	691	339	1.67	73	72	87	18.7
3	1800	12.0	712	8.9	80	90	339	11.9	0.4	513	336	2.61	134	91	143	17.3
4	1800	24.0	730	12.5	81	91	408	11.7	0.5	592	322	3.72	239	250	265	16.4
5	1800	36.0	736	15.9	80	91	497	11.2	0.6	553	307	4.49	351	300	346	14.5
6	1800	49.0	726	19.3	80	92	573	11.2	0.6	612	337	5.46	477	463	495	12.6
7	1800	60.0	730	22.6	[illegible]	92	667	[illegible]	0.8	533	[illegible]	6.43	641	595	678	11.4
8	1800	72.0	712	28.7	82	92	824	11.5	[illegible]	671	846	7.61	822	850	859	9.2
9	1800	84.0	724	34.6	83	92	941	11.4	1.2	829	2108	8.72	1004	1004	1015	7.1
10	1800	96.0	712	39.5	84	93	1063	10.9	1.1	730	6630	9.96	1072	1138	1138	4.7
11	700	———	291	1.6	86	90	611	1.9	0.1	592	258	1.61	114	125	154	18.2
12	2500	109.	950	44.1	82	95	955	20.1	1.4	888	1761	8.89	1287	1415	1415	6.7
13	2500	96.7	960	38.8	84	97	956	20.0	1.3	711	898	8.07	1194	1249	1282	8.2
14	2500	82.5	955	34.3	85	97	872	20.2	1.2	701	533	7.09	966	1024	1024	9.6
15	2500	68.3	965	29.7	84	100	773	20.4	1.2	651	412	6.14	745	762	794	11.0
16	2500	55.0	965	25.2	83	100	682	20.9	1.1	701	349	5.33	549	547	584	12.3
17	2500	41.7	976	21.1	81	100	609	20.1	1.0	642	352	4.43	396	370	393	13.1
18	2500	27.5	967	17.1	81	99	514	20.8	0.7	711	377	3.70	273	264	306	16.5
19	2500	13.3	962	13.7	80	98	444	20.8	0.8	661	384	2.92	162	154	202	17.9
20	2500	———	972	10.1	82	94	342	20.7	0.6	553	362	1.77	107	87	154	18.5
21	700	———	281	1.1	85	93	264	1.9	0.1	385	247	1.61	135	125	145	19.0

ENGINE INTERNATIONAL D407 DATE 5/10/72 WET BULB TEMP., °F 66

RUN 6 BAROMETER, in Hg 29.07 DRY BULB TEMP., °F 73

MODE	ENGINE SPEED RPM	OBSERVED POWER hp	AIR FLOW lbm/hr	FUEL FLOW lbm/hr	TEMPERATURE °F INTAKE AIR		EXHAUST	RESTRICTION INTAKE in H_2O	EXHAUST in Hg	FIA HC ppmC	NDIR CO ppm	NDIR CO_2 %	NDIR NO ppm	C.L. NO ppm	C.L. NO_x ppm	O_2 %
1	700	—	304	1.6	82	90	427	2.2	0.1	553	271	1.27	128	107	155	18.9
2	1800	—	740	5.6	81	90	282	11.9	0.3	829	352	1.47	67	48	87	18.6
3	1800	12.0	712	8.7	79	90	316	11.4	0.4	691	361	2.35	148	125	173	17.3
4	1800	24.0	730	12.3	80	90	406	11.7	0.5	750	311	3.24	274	218	266	15.8
5	1800	36.0	736	15.8	80	90	493	11.7	0.5	632	422	4.18	368	334	381	14.3
6	1800	48.0	726	19.0	81	90	597	11.5	0.6	750	339	5.13	545	484	525	12.6
7	1800	60.0	729	23.4	81	91	669	11.2	0.7	691	470	6.30	737	717	754	11.0
8	1800	72.0	713	27.5	82	91	793	11.2	0.9	849	923	7.32	871	897	908	9.1
9	1800	84.0	726	32.5	84	92	915	11.4	1.1	869	2147	8.40	1067	1086	1120	7.2
10	1800	96.6	712	39.2	85	93	1062	11.2	1.2	592	7035	9.44	1189	1189	1233	4.5
11	700	—	292	1.1	91	91	568	1.9	0.1	434	248	1.32	142	126	155	18.3
12	2500	108.	950	43.4	84	96	953	20.2	1.4	730	1717	8.32	1418	1335	1379	6.9
13	2500	95.8	959	40.2	86	99	958	20.3	1.3	582	848	7.55	1277	1178	1223	8.2
14	2500	82.5	956	33.7	86	100	861	20.2	1.2	533	524	6.87	980	959	981	9.7
15	2500	67.5	966	29.2	85	102	764	20.7	1.1	513	403	5.88	749	701	738	11.2
16	2500	54.2	965	24.7	85	102	687	20.7	1.0	553	350	5.07	544	507	549	12.5
17	2500	40.0	977	20.6	84	102	592	21.0	0.8	474	353	4.24	375	347	394	13.6
18	2500	27.5	966	18.1	84	102	513	20.7	0.7	543	356	3.52	273	227	274	14.7
19	2500	12.5	964	12.2	82	101	444	20.7	0.7	454	382	2.67	161	115	153	15.8
20	2500	—	972	10.6	82	99	375	20.9	0.6	572	384	2.03	93	86	125	16.8
21	700	—	280	1.6	86	93	266	1.9	0.1	434	282	1.61	149	87	145	17.8

ENGINE INTERNATIONAL D407 DATE 5/11/72 WET BULB TEMP., °F 65

RUN 7 BAROMETER, in Hg 29.12 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE, in H$_2$O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO$_2$, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO$_x$, ppm	O$_2$, %
1	700	———	301	1.1	95	109	——	2.3	0.0	530	271	1.41	156	116	145	18.5
2	2100	———	838	6.7	92	101	——	15.5	0.3	760	385	1.82	93	58	96	17.9
3	2100	26.6	840	14.5	91	99	——	15.6	0.6	650	367	3.59	280	227	284	15.4
4	2100	52.5	838	23.8	90	99	——	15.3	0.6	640	428	5.47	598	528	565	12.5
5	2100	78.4	836	31.9	91	100	——	15.2	0.9	740	743	7.09	1084	966	1047	9.3
6	2100	105.	818	43.8	92	103	——	14.8	0.8	840	5793	9.54	1349	1244	1244	4.9
7	700	———	294	1.1	94	103	——	1.9	0.0	510	236	1.47	177	135	155	18.4
8	2300	110.	895	46.2	92	90	——	17.2	1.2	970	4241	9.47	1521	1413	1423	5.3
9	2300	82.8	894	32.8	93	91	——	17.7	1.1	705	683	7.32	1248	1158	1203	9.2
10	2300	55.2	907	24.0	94	93	——	17.9	0.8	665	405	5.40	598	556	565	12.4
11	2300	27.6	891	15.2	92	95	——	17.7	0.7	680	355	3.70	279	236	321	15.2
12	2300	———	898	8.4	92	97	——	17.8	0.5	760	384	2.03	93	96	125	17.7
13	700	———	306	1.5	93	100	——	2.2	0.0	555	247	1.52	135	126	135	18.4

ENGINE INTERNATIONAL D407 DATE 5/9/72 WET BULB TEMP., °F 67

MAPPING RUN M-1 BAROMETER, in Hg 29.06 DRY BULB TEMP., °F 78

	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F			RESTRICTIONS		FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
MODE					INTAKE AIR	FUEL	EXH-AUST	INTAKE in H_2O	EXHAUST in Hg							
1	700	———	323	1.6	95	101	——	2.3	0.0	580	271	1.41	142	102	145	18.8
2	2100	———	837	7.0	92	99	——	15.2	0.4	690	362	1.82	93	58	101	18.2
3	2100	26.6	841	14.2	92	100	——	15.4	0.5	610	355	3.58	273	217	274	15.4
4	2100	52.5	845	22.4	91	104	——	15.4	0.7	630	383	5.40	606	501	538	12.5
5	2100	78.4	832	32.1	91	99	——	15.1	1.1	740	776	7.47	1079	917	940	9.2
6	2100	105.	808	43.6	92	95	——	14.4	1.0	790	6171	9.70	1355	1175	1185	4.9
7	700	———	328	1.1	95	97	——	2.4	0.0	500	224	1.47	170	155	179	18.6
8	2300	110.	875	45.9	93	98	——	17.0	1.2	1020	5097	9.63	1540	1397	1452	5.3
9	2300	82.8	892	34.1	93	101	——	17.6	1.0	660	704	7.62	1275	1131	1154	9.1
10	2300	55.2	906	24.9	93	101	——	17.8	0.8	615	393	5.66	621	545	554	12.2
11	2300	27.6	910	16.3	94	102	——	18.3	0.7	655	343	3.88	308	259	306	15.1
12	2300	———	905	8.3	92	102	——	18.2	0.6	720	361	2.03	107	106	125	17.7
13	700	———	285	1.4	93	96	——	1.9	0.0	565	224	1.56	149	125	130	18.3

ENGINE INTERNATIONAL D407 DATE 5/9/72 WET BULB TEMP, °F 67

MAPPING RUN M-2 BAROMETER, in Hg 29.08 DRY BULB TEMP, °F 75

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	BOOST PRESS, in Hg	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppm C	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C. L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	800	—	378	3.0	65	90	262	0.0	1.8	0.0	1256	692	1.53	46	85	32	—
2	1500	—	644	7.8	65	88	338	0.7	4.8	0.2	3200	3104	1.48	9	42	16	—
3	1500	13.0	671	10.6	65	90	420	1.8	5.3	0.2	2400	1061	3.11	45	110	62	—
4	1500	26.5	718	14.8	66	91	538	3.4	6.2	0.2	1488	634	4.18	176	204	176	—
5	1500	39.0	747	18.4	67	92	635	5.5	6.4	0.3	1312	451	5.18	278	290	266	—
6	1500	52.5	784	23.0	67	94	741	8.1	7.2	0.4	1296	454	6.05	376	358	349	—
7	1500	65.0	793	26.2	68	95	834	10.0	7.4	0.5	1280	488	6.86	482	471	466	—
8	1500	78.5	842	29.4	70	94	947	13.3	8.3	0.6	1072	662	7.58	594	608	599	—
9	1500	91.5	879	36.5	70	94	1010	16.2	9.0	0.8	736	1332	8.44	709	720	711	—
10	1500	102.0	867	39.6	72	97	1090	18.6	9.4	0.9	592	2409	8.17	736	754	767	—
11	800	—	378	2.8	71	99	520	0.5	1.7	0.0	528	584	1.53	122	141	112	—
12	2200	135.7	1453	56.0	70	96	997	26.5	25.0	2.7	656	483	7.92	1152	931	917	—
13	2200	120.3	1415	51.6	73	97	990	24.8	23.5	2.5	640	409	7.68	862	851	837	—
14	2200	103.4	1351	44.6	73	95	944	21.2	21.0	2.2	656	236	6.99	647	691	682	—
15	2200	86.5	1310	39.8	75	94	895	18.4	20.5	1.9	688	136	6.45	530	556	551	—
16	2200	68.2	1187	33.0	74	94	820	14.3	16.7	1.6	640	150	5.78	366	387	382	—
17	2200	52.1	1141	27.6	74	95	745	11.0	15.5	1.4	592	164	4.99	295	306	292	—
18	2200	33.7	1080	22.6	74	94	664	7.7	13.7	1.2	704	255	4.46	215	222	208	—
19	2200	17.6	1033	17.8	74	94	586	5.4	12.5	0.8	768	348	3.59	157	167	143	—
20	2200	—	953	12.0	74	93	475	2.5	10.7	0.6	992	537	2.59	64	92	58	—
21	800	—	359	2.6	73	93	362	0.0	1.7	0.0	1008	449	1.53	55	89	49	—

ENGINE JOHN DEERE 6404 DATE 3/3/72 WET BULB TEMP., °F 54

RUN 1 BAROMETER, in Hg 29.20 DRY BULB TEMP., °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	BOOST PRESS, in Hg	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppm C	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	800	———	370	2.5	64	80	472	0.4	1.5	0.0	1184	301	1.52	92	87	73	———
2	1500	———	663	7.4	64	80	413	1.2	5.0	0.2	1776	944	1.77	37	87	35	———
3	1500	13.0	668	10.2	64	85	456	1.8	5.3	0.2	1456	172	2.97	73	95	60	———
4	1500	26.0	674	14.0	64	85	541	3.5	5.3	0.2	1168	474	4.03	165	183	149	———
5	1500	39.0	730	18.0	64	88	631	5.0	6.0	0.4	1088	302	4.95	263	255	234	———
6	1500	52.5	750	22.0	64	90	741	7.2	6.5	0.5	1088	300	5.75	364	329	316	———
7	1500	65.0	778	26.2	64	92	837	9.6	7.0	0.6	1120	359	6.67	468	431	427	———
8	1500	78.0	814	30.5	64	94	918	12.4	8.0	0.8	1168	483	7.34	581	539	530	———
9	1500	91.0	870	36.0	64	96	994	15.7	9.0	1.0	1136	1080	8.00	697	643	638	———
10	1500	103.5	922	40.8	66	97	1074	18.5	9.5	1.2	960	1986	8.38	848	783	744	———
11	800	———	350	2.5	65	100	630	0.5	1.5	0.0	864	353	1.39	112	78	73	———
12	2200	134.9	1446	56.3	64	102	945	23.2	25.0	3.0	800	462	9.06	1240	1155	1128	———
13	2200	121.0	1369	50.8	64	90	993	23.5	22.5	2.9	816	320	7.34	943	849	835	———
14	2200	104.1	1315	44.8	65	90	951	20.7	20.5	2.6	784	159	6.78	666	603	603	———
15	2200	86.5	1259	39.0	65	90	897	17.2	18.5	2.2	736	99	6.15	517	444	444	———
16	2200	69.7	1231	34.8	66	90	833	14.4	17.5	2.0	704	87	5.75	440	390	390	———
17	2200	51.3	1136	28.0	66	90	754	10.5	15.0	1.7	640	138	4.96	294	281	281	———
18	2200	34.5	1050	22.5	66	90	673	7.1	13.0	1.4	640	436	4.30	219	202	193	———
19	2200	27.9	1036	20.5	66	88	625	5.9	12.5	1.2	656	454	3.50	158	183	179	———
20	2200	———	976	12.5	67	86	497	3.1	11.5	0.9	816	562	2.53	83	79	59	———
21	800	———	340	2.5	67	86	249	0.0	1.5	0.0	784	567	2.56	83	80	59	———

ENGINE JOHN DEERE 6404 DATE 3/6/72 WET BULB TEMP, °F 60

RUN 2 BAROMETER, in Hg 29.42 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	BOOST PRESS, in Hg	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppm C	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	800	———	359	2.5	70	90	488	0.3	1.7	0.0	768	492	1.66	56	88	68	———
2	1500	———	640	7.8	69	90	401	0.8	4.8	0.2	1408	1138	2.07	9	37	25	———
3	1500	12.5	646	10.0	71	90	462	1.5	5.0	0.2	1136	987	3.14	37	85	57	———
4	1500	26.0	688	13.8	70	90	550	3.2	5.7	0.3	960	612	4.22	138	174	144	———
5	1500	39.5	734	17.8	70	90	655	5.1	6.0	0.4	928	435	5.29	225	250	240	———
6	1500	53.0	786	23.2	69	90	753	8.1	7.2	0.4	976	392	6.24	315	323	323	———
7	1500	65.5	795	26.5	69	90	834	10.0	7.4	0.5	1072	491	7.03	418	422	422	———
8	1500	77.5	817	30.6	70	90	931	12.6	8.2	0.5	1152	590	7.71	516	512	512	———
9	1500	91.0	864	36.2	70	90	1017	15.7	8.7	0.6	1200	1235	8.50	641	635	635	———
10	1500	102.5	881	41.4	71	91	1082	18.8	9.5	0.7	1056	2228	9.04	827	789	755	———
11	800	———	359	2.5	70	92	507	0.3	1.7	0.0	912	397	1.80	84	98	93	———
12	2200	134.9	1468	56.4	70	94	958	25.9	24.5	3.0	896	550	7.96	1129	1185	1130	———
13	2200	121.0	1393	51.0	69	92	975	24.1	23.0	2.7	880	452	7.31	858	847	835	———
14	2200	103.4	1327	44.6	69	91	944	21.2	20.7	2.6	848	339	6.76	641	614	614	———
15	2200	87.3	1285	39.8	70	90	892	18.3	19.7	2.2	816	265	6.36	511	496	491	———
16	2200	68.9	1174	32.8	69	91	824	13.8	16.5	2.0	752	267	5.70	381	363	358	———
17	2200	52.1	1115	29.2	70	90	755	10.6	15.0	1.6	688	269	5.74	383	365	361	———
18	2200	34.5	1062	22.4	70	91	671	7.4	13.3	1.4	704	369	4.35	207	195	192	———
19	2200	17.6	1017	17.8	70	92	590	4.9	12.5	1.2	752	483	3.55	149	136	129	———
20	2200	———	936	11.8	70	92	480	2.0	10.5	0.8	880	622	2.68	74	76	52	———
21	800	———	349	2.5	70	91	213	[illegible]	1.5	0.0	784	521	1.54	65	68	45	———

ENGINE JOHN DEERE 6404 DATE 3/6/72 WET BULB TEMP., °F 64

RUN 3 BAROMETER, in Hg 29.21 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	BOOST PRESS, in Hg	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppm C	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	800	—	359	2.6	70	94	463	0.2	1.7	0.0	768	523	1.63	83	78	75	—
2	1500	—	644	7.4	70	94	420	1.0	5.2	0.1	1392	1160	2.03	27	33	26	—
3	1500	12.5	661	10.2	70	94	470	1.8	5.5	0.2	1152	983	2.95	63	82	55	—
4	1500	26.0	703	14.2	70	95	544	3.4	6.0	0.2	976	680	4.14	145	154	132	—
5	1500	39.0	718	17.8	70	94	657	5.2	6.3	0.3	896	480	5.06	241	229	218	—
6	1500	52.5	748	22.4	70	94	763	7.6	6.8	0.4	944	487	6.12	339	304	304	—
7	1500	65.5	820	27.5	70	93	849	10.6	8.0	0.5	1008	508	6.78	433	397	397	—
8	1500	78.0	833	31.2	70	92	926	13.1	8.3	0.6	1040	579	7.57	540	475	475	—
9	1500	91.0	887	36.8	70	92	1017	16.6	9.3	0.7	1056	1254	8.22	666	602	597	—
10	1500	102.5	859	39.8	70	90	1096	18.0	8.7	0.7	1008	2328	8.88	839	735	735	—
11	800	—	369	2.6	70	90	546	0.4	1.7	0.0	944	475	0.86	84	97	83	—
12	2200	136.4	1466	56.4	70	90	989	26.0	25.0	2.8	1024	590	7.82	1185	1096	1069	—
13	2200	119.5	1391	50.6	70	90	982	23.8	22.8	2.7	944	456	7.18	883	845	845	—
14	2200	104.1	1325	45.4	70	90	950	20.9	20.7	2.6	928	332	6.91	677	657	657	—
15	2200	86.5	1297	40.4	70	90	899	18.1	20.0	2.1	880	259	6.38	513	495	490	—
16	2200	68.9	1182	33.6	70	90	832	14.2	17.3	1.9	784	248	5.72	394	383	374	—
17	2200	51.3	1113	27.5	70	90	759	10.6	14.8	1.6	720	289	5.07	281	266	262	—
18	2200	34.5	1057	22.4	70	90	673	7.3	13.3	1.3	736	368	4.27	203	194	188	—
19	2200	17.6	1016	17.5	70	90	590	4.9	12.3	1.1	752	461	3.48	146	138	127	—
20	2200	—	972	12.6	70	91	478	2.6	11.0	0.8	864	598	2.42	63	82	54	—
21	800	—	369	2.3	70	90	342	0.1	1.7	0.0	768	499	1.38	55	67	37	—

ENGINE JOHN DEERE 6404 DATE 3/6/72 WET BULB TEMP, °F 66

RUN 4 BAROMETER, in Hg 29.23 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	BOOST PRESS, in Hg	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	880	———	385	2.5	71	96	517	0.2	1.7	0.0	688	468	1.64	73	66	63	———
2	1700	———	738	8.2	71	96	467	1.6	6.5	0.2	1120	964	2.03	27	26	14	———
3	1700	25.5	802	16.0	72	97	595	3.9	7.7	0.3	832	586	4.00	136	139	112	———
4	1700	51.5	870	25.2	72	98	778	9.0	9.0	0.4	848	360	5.83	298	271	262	———
5	1700	76.5	959	34.6	73	99	905	14.8	10.7	0.7	944	517	7.15	530	485	480	———
6	1700	101.0	1074	42.4	73	100	1017	21.2	13.5	1.1	960	1107	8.20	912	847	847	———
7	870	———	376	2.4	74	100	560	0.3	1.7	0.0	720	456	1.51	73	72	67	———
8	1900	126.7	1233	49.0	73	101	976	21.9	17.3	1.5	960	739	7.95	1029	957	944	———
9	1900	95.0	1077	38.8	73	100	954	17.3	15.5	1.2	928	443	7.02	612	558	558	———
10	1900	63.3	1002	29.2	74	98	857	11.8	11.7	1.0	800	286	5.58	340	300	295	———
11	1900	31.7	890	18.4	73	98	702	5.9	9.5	0.6	704	457	4.00	164	150	141	———
12	1900	———	837	9.8	73	97	504	2.4	8.3	0.3	864	639	2.16	54	44	40	———
13	850	———	357	2.4	73	98	414	0.2	1.7	0.0	816	537	1.31	45	44	36	———

ENGINE JOHN DEERE 6404 DATE 3/7/72 WET BULB TEMP., °F 69

MAPPING RUN M-1 BAROMETER, in Hg 29.13 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH. PRE-TURBO	BOOST PRESS, in Hg	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	860	———	367	2.5	74	98	445	0.2	1.7	0.0	104	527	1.63	55	71	55	———
2	1700	———	733	8.4	74	98	422	1 3	6.5	0.2	1120	1030	2.16	27	42	25	———
3	1700	25.0	793	16.6	74	96	565	3.8	7.5	0.3	848	600	4.13	136	154	124	———
4	1700	51.0	874	25.4	75	95	742	8.8	9.0	0.5	864	385	5.97	308	284	284	———
5	1700	75.5	981	35.2	75	93	888	15.0	11.3	0.8	992	517	7.22	518	494	485	———
6	1700	102.0	1020	46.0	76	94	1030	20.9	12.7	1.2	960	1340	8.33	910	854	844	———
7	870	———	367	2.8	76	92	612	0.3	1.7	0.0	752	455	1.77	83	96	82	———
8	1900	125.4	1233	49.5	76	94	995	22.7	17.5	1.6	960	826	8.22	1071	982	955	———
9	1900	95.0	1054	37.6	76	94	956	17.2	13.7	1.2	928	468	7.16	624	571	553	———
10	1900	62.7	977	28.4	77	93	860	11.4	11.7	0.9	816	309	5.97	350	326	326	———
11	1900	31.0	861	17.6	78	94	723	5.7	9.8	0.6	720	469	4.40	174	173	168	———
12	1900	———	824	9.8	77	92	540	2.5	8.3	0.4	864	650	2.42	63	71	54	———
13	850	———	346	2.2	77	92	419	0.2	1.7	0.0	752	504	1.56	54	72	64	———

ENGINE JOHN DEERE 6404 DATE 3/7/72 WET BULB TEMP, °F 69

MAPPING RUN M-2 BAROMETER, in Hg 29.15 DRY BULB TEMP, °F 78

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	680	———	93	1.3	73	77	———	0.8	0.1	138	415	2.54	———	227	422	———
2	1400	———	175	1.9	72	76	———	5.3	0.3	138	332	2.28	———	67	67	———
3	1400	2.0	176	3.1	72	76	———	4.8	0.4	147	219	393	———	179	197	———
4	1400	4.0	175	3.4	73	76	———	4.4	0.4	158	213	4.25	———	210	233	———
5	1400	6.1	174	4.2	73	76	———	5.3	0.5	189	262	5.17	———	276	300	———
6	1400	8.0	171	4.5	73	74	———	4.5	0.5	209	269	5.77	———	298	320	———
7	1400	10.1	172	5.5	73	73	———	4.3	0.5	196	282	6.68	———	297	316	———
8	1400	12.1	170	6.4	71	73	———	4.2	0.5	175	287	7.81	———	312	319	———
9	1400	14.[illegible]	167	7.1	71	73	———	3.9	0.6	140	299	8.66	———	309	316	———
10	1400	16.1	163	8.4	72	74	———	3.5	0.5	241	1414	10.22	———	247	255	———
11	700	———	89	1.1	73	74	———	1.8	0.1	118	344	2.50	———	211	223	———
12	2400	28.2	281	15.6	72	74	———	10.0	1.8	184	2403	10.78	———	310	317	———
13	2400	24.5	281	12.3	74	74	———	9.6	1.7	202	442	8.64	———	354	354	———
14	2400	21.2	281	11.6	75	76	———	9.2	1.6	256	398	8.24	———	361	372	———
15	2400	17.3	281	9.7	74	76	———	9.0	1.4	328	414	6.78	———	323	323	———
16	2400	14.1	287	8.8	75	77	———	9.2	1.3	196	450	5.71	———	226	235	———
17	2400	9.[illegible]	287	6.8	74	77	———	9.5	1.0	206	286	4.99	———	160	192	———
18	2400	7.1	293	6.3	74	77	———	11.8	1.0	230	313	4.38	———	125	154	———
19	2400	3.2	287	5.2	73	77	———	11.9	0.9	224	311	3.71	———	83	126	———
20	2400	———	299	4.1	72	77	———	13.1	0.9	161	427	1.06	———	54	77	———
21	700	———	91	1.1	71	77	———	1.2	0.1	81	304	2.50	———	157	199	———

ENGINE MERCEDES-BENZ OM636 DATE 1/4/73 WET BULB TEMP., °F 57

RUN 1 BAROMETER, in Hg 29.33 DRY BULB TEMP., °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	—	92	1.4	77	107	—	1.3	0.1	231	601	2.81	—	164	208	—
2	1400	—	175	2.3	73	100	—	4.8	0.3	164	297	2.62	—	69	104	—
3	1400	2.0	175	3.2	74	96	—	4.5	0.3	149	197	3.71	—	145	180	—
4	1400	4.0	173	3.5	71	94	—	4.1	0.4	147	241	3.98	—	164	196	—
5	1400	6.1	171	4.2	71	92	—	4.0	0.4	169	205	5.45	—	228	269	—
6	1400	8.0	171	4.9	71	91	—	3.9	0.5	176	265	5.97	—	255	279	—
7	1400	10.1	168	5.7	70	90	—	3.6	0.5	175	292	7.06	—	285	308	—
8	1400	12.1	168	6.4	70	90	—	3.4	0.6	172	314	7.74	—	277	307	—
9	1400	14.1	173	7.8	73	92	—	3.3	0.6	160	415	9.31	—	260	262	—
10	1400	16.1	166	8.6	75	94	—	2.9	0.6	254	1466	[illegible]	—	238	239	—
11	700	—	91	1.4	76	95	—	1.6	0.1	162	419	2.32	—	245	245	—
12	2400	28.2	281	15.1	74	102	—	10.0	1.9	130	1679	10.80	—	285	285	—
13	2400	24.5	280	13.1	78	100	—	9.0	1.8	166	449	9.59	—	322	322	—
14	2400	21.2	285	11.6	79	99	—	9.0	1.7	198	395	8.82	—	323	[illegible]	—
15	2400	17.3	285	10.1	79	99	—	9.1	1.5	298	462	7.25	—	284	284	—
16	2400	14.1	286	8.9	78	99	—	9.4	1.4	316	391	6.43	—	244	251	—
17	2400	9.1	292	7.4	78	99	—	10.1	1.1	376	361	5.29	—	152	167	—
18	2400	7.0	292	6.6	77	99	—	10.5	1.0	399	375	4.81	—	113	147	—
19	2400	3.2	292	5.4	76	91	—	11.1	1.0	352	367	3.64	—	74	103	—
20	2400	—	292	4.0	75	79	—	12.0	0.9	272	469	2.37	—	32	67	—
21	700	—	89	1.4	74	[illegible]	—	1.3	0.1	140	352	2.54	—	147	178	—

ENGINE MERCEDES-BENZ OM636 DATE 1/4/73 WET BULB TEMP, °F 57

RUN 2 BAROMETER, in Hg 29.28 DRY BULB TEMP., °F 70

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	———	92	1.2	74	110	———	1.3	0.1	270	457	2.52	———	138	176	———
2	1400	———	172	1.8	74	110	———	2.9	0.2	338	547	2.39	———	48	94	———
3	1400	2.0	172	2.9	74	110	———	3.9	0.3	267	261	3.84	———	130	170	———
4	1400	4.0	174	3.6	75	107	———	4.0	0.4	268	252	4.52	———	176	202	———
5	1400	6.1	171	4.2	75	105	———	3.7	0.4	237	217	4.88	———	212	243	———
6	1400	8.0	169	4.8	76	103	———	3.4	0.5	240	224	6.23	———	389	412	———
7	1400	10.1	167	5.4	77	102	———	3.3	0.5	236	232	6.91	———	314	305	———
8	1400	12.1	168	6.4	77	101	———	3.1	0.6	216	253	8.18	———	302	304	———
9	1400	14.1	167	7.5	79	101	———	3.0	0.6	206	317	8.84	———	298	299	———
10	1400	16.1	161	8.4	81	100	———	2.9	0.6	332	1560	10.17	———	253	253	———
11	700	———	92	1.2	83	100	———	1.0	0.1	152	291	2.52	———	216	231	———
12	2400	28.2	272	15.1	80	101	———	9.5	1.9	186	2626	11.72	———	310	318	———
13	2400	24.5	280	13.7	87	100	———	8.9	1.8	192	1009	10.01	———	303	303	———
14	2400	21.2	282	11.9	91	101	———	9.0	1.7	210	463	8.90	———	319	325	———
15	2400	17.2	281	10.5	92	102	———	9.3	1.6	262	400	[illegible].70	———	305	305	———
16	2400	14.1	282	9.2	91	103	———	9.4	1.4	400	438	7.11	———	258	258	———
17	2400	9.1	282	7.4	90	103	———	10.3	1.2	440	377	5.43	———	182	188	———
18	2400	7.1	290	6.8	81	90	———	9.8	1.1	512	338	4.98	———	139	158	———
19	2400	3.2	290	5.4	83	90	———	9.5	1.0	504	387	4.09	———	82	120	———
20	2400	———	293	4.2	83	92	———	9.9	1.0	326	418	2.87	———	39	73	———
21	700	———	90	1.1	83	93	———	1.1	0.1	171	293	2.51	———	134	175	———

ENGINE MERCEDES-BENZ OM636 DATE 1/5/73 WET BULB TEMP., °F 57

RUN 3 BAROMETER, in Hg 29.15 DRY BULB TEMP., °F 70

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	—	91	1.1	86	103	—	0.9	0.1	120	378	2.53	—	156	171	—
2	1400	—	172	1.9	85	104	—	5.7	0.3	133	274	2.51	—	60	95	—
3	1400	2.0	175	3.1	84	104	—	4.8	0.3	162	260	3.97	—	129	164	—
4	1400	4.0	171	3.6	83	104	—	4.4	0.4	183	262	4.63	—	165	197	—
5	1400	6.1	169	4.3	83	103	—	4.0	0.5	185	244	5.31	—	207	244	—
6	1400	8.0	166	4.7	83	103	—	3.8	0.5	206	278	6.42	—	249	281	—
7	1400	10.1	167	5.8	84	103	—	3.7	0.5	194	279	7.22	—	265	283	—
8	1400	12.1	164	6.1	85	103	—	3.4	0.6	164	256	8.34	—	289	291	—
9	1400	14.1	162	7.3	86	103	—	3.3	0.6	200	459	9.56	—	253	255	—
10	1400	16.1	173	8.9	88	103	—	3.1	0.7	260	1458	10.45	—	246	247	—
11	700	—	89	1.1	89	104	—	1.1	0.1	131	334	2.54	—	183	187	—
12	2400	28.2	277	15.2	85	104	—	9.6	1.9	112	2435	10.84	—	280	280	—
13	2400	24.5	275	13.4	92	104	—	8.8	1.8	172	722	9.94	—	310	315	—
14	2400	21.2	274	11.6	96	105	—	8.6	1.7	198	405	8.77	—	328	331	—
15	2400	17.3	274	10.1	96	106	—	8.4	1.6	282	445	7.42	—	301	301	—
16	2400	14.1	274	8.9	96	107	—	8.5	1.4	380	485	6.94	—	278	280	—
17	2400	9.1	275	7.3	95	107	—	8.7	1.1	488	367	5.40	—	188	192	—
18	2400	7.1	281	6.6	93	106	—	9.0	1.0	556	373	4.89	—	138	156	—
19	2400	3.2	281	5.5	92	106	—	10.3	1.0	480	363	3.96	—	87	109	—
20	2400	—	281	3.9	92	106	—	10.9	0.9	358	483	2.99	—	91	67	—
21	700	—	83	1.2	91	106	—	1.0	0.1	103	380	2.67	—	148	190	—

ENGINE MERCEDES-BENZ OM636 DATE 1/5/73 WET BULB TEMP., °F 62

RUN 4 BAROMETER, in Hg 29.13 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	—	95	1.2	56	89	—	1.0	1.0	280	474	2.67	228	180	194	—
2	1400	—	180	2.6	54	89	—	5.9	5.9	206	347	2.45	84	42	78	—
3	1400	2.1	175	3.2	53	88	—	5.0	5.0	177	236	3.41	159	102	140	—
4	1400	4.2	174	3.7	52	87	—	4.4	4.4	165	173	4.01	209	182	217	—
5	1400	6.3	173	4.4	52	88	—	4.0	4.0	188	191	5.10	225	224	265	—
6	1400	8.4	173	5.3	[illegible]	88	—	3.8	3.8	174	168	5.68	276	267	286	—
7	1400	10.5	175	5.7	[illegible]	89	—	3.5	3.5	168	170	6.41	323	294	317	—
8	1400	12.6	170	6.6	54	91	—	3.3	3.3	140	186	7.70	298	288	289	—
9	1400	14.7	175	7.9	56	95	—	3.0	3.0	140	195	8.63	297	282	286	—
10	1400	16.8	166	8.5	56	96	—	2.8	2.8	200	771	9.75	257	239	239	—
11	700	—	91	1.2	57	96	—	1.0	1.0	108	334	2.40	191	161	172	—
12	2400	29.4	279	15.4	63	97	—	10.0	10.0	120	1748	10.55	341	302	304	—
13	2400	25.8	277	13.6	72	102	—	8.7	8.7	140	584	9.63	370	321	324	—
14	2400	22.1	283	11.4	73	104	—	9.4	9.4	200	351	7.89	402	344	344	—
15	2400	18.5	286	9.8	72	104	—	12.1	12.1	260	378	6.81	354	294	301	—
16	2400	14.7	286	9.1	71	104	—	12.2	12.2	432	384	5.73	371	218	232	—
17	2400	11.1	289	7.4	70	104	—	12.5	12.5	376	286	5.07	328	186	200	—
18	2400	7.4	296	6.3	69	103	—	12.9	12.9	500	293	4.28	148	117	144	—
19	2400	3.7	296	5.3	68	103	—	12.8	12.8	463	355	3.62	101	70	109	—
20	2400	—	296	4.5	67	102	—	13.0	13.0	242	448	2.67	55	35	68	—
21	700	—	90	1.0	66	102	—	1.0	1.0	145	347	2.40	143	120	160	—

ENGINE MERCEDES-BENZ OM636 DATE 1/8/73 WET BULB TEMP, °F 44

RUN 5 BAROMETER, in Hg 29.62 DRY BULB TEMP, °F 55

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	—	94	1.2	67	95	—	1.0	0.1	103	410	2.41	150	131	154	—
2	1400	—	176	2.2	65	99	—	5.9	0.3	109	308	2.56	77	62	98	—
3	1400	2.1	175	3.1	62	102	—	4.9	0.4	133	293	3.47	139	111	153	—
4	1400	4.2	175	3.8	62	105	—	4.9	0.4	132	264	3.89	187	152	191	—
5	1400	6.3	173	4.3	62	107	—	4.2	0.4	140	242	4.83	269	220	255	—
6	1400	8.4	172	5.3	62	108	—	4.0	0.5	151	259	6.01	345	271	309	—
7	1400	10.5	172	5.8	63	109	—	3.9	0.5	132	248	6.50	387	317	335	—
8	1400	12.6	169	6.9	63	109	—	3.5	0.5	120	277	8.17	356	327	327	—
9	1400	14.7	169	7.6	67	109	—	3.3	0.6	115	265	8.83	359	304	304	—
10	1400	16.8	164	8.7	68	108	—	3.1	0.6	144	827	10.11	285	277	277	—
11	700	—	91	1.2	71	107	—	1.0	0.1	104	422	2.55	190	170	182	—
12	2400	29.4	275	15.2	76	109	—	9.4	1.8	96	1548	10.90	347	335	336	—
13	2400	25.8	274	13.4	81	103	—	9.5	1.8	142	583	9.83	376	359	363	—
14	2400	22.1	280	11.6	81	101	—	9.3	1.7	180	349	8.44	400	374	374	—
15	2400	18.5	280	10.1	81	101	—	9.8	1.6	260	381	7.27	362	335	340	—
16	2400	14.7	280	8.8	80	101	—	11.8	1.3	300	330	6.41	310	270	290	—
17	2400	11.1	287	7.4	78	101	—	12.2	1.1	404	315	5.36	236	213	225	—
18	2400	7.4	287	6.4	78	101	—	12.5	1.0	536	278	4.48	159	136	158	—
19	2400	3.8	287	5.4	77	102	—	12.3	1.0	532	320	3.75	73	87	119	—
20	2400	—	293	4.3	76	102	—	12.9	1.0	300	371	2.78	36	45	76	—
21	700	—	87	1.2	75	103	—	1.0	0.1	130	221	2.40	135	124	160	—

ENGINE MERCEDES-BENZ OM636 — DATE 1/9/73 — WET BULB TEMP., °F 45

RUN 6 — BAROMETER, in Hg 29.58 — DRY BULB TEMP., °F 60

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	—	89	1.2	73	97	—	1.2	0.1	71	360	2.33	166	163	172	—
2	1400	—	173	2.2	73	96	—	5.7	0.3	118	372	2.55	83	66	109	—
3	1400	2.1	173	3.2	71	94	—	5.2	0.3	128	295	3.60	152	131	165	—
4	1400	4.2	170	3.8	71	94	—	4.9	0.4	135	264	4.29	230	194	227	—
5	1400	6.3	169	4.1	71	95	—	4.4	0.4	146	264	4.91	279	231	258	—
6	1400	8.4	170	5.2	71	96	—	4.2	0.5	150	272	6.03	338	280	304	—
7	1400	10.5	167	5.8	71	99	—	4.0	0.5	132	258	7.08	389	326	344	—
8	1400	12.6	167	6.5	72	99	—	3.7	0.5	132	280	7.91	359	339	339	—
9	1400	14.7	166	7.8	74	102	—	3.7	0.5	136	299	9.34	296	293	293	—
10	1400	16.8	166	8.6	75	103	—	3.5	0.6	202	927	10.15	251	259	259	—
11	700	—	89	1.3	77	104	—	1.1	0.1	102	359	2.53	182	169	180	—
12	2400	29.4	276	14.9	73	104	—	9.7	1.8	84	1830	10.69	347	322	335	—
13	2400	25.8	274	14.1	81	103	—	8.8	1.8	110	892	10.09	361	325	335	—
14	2400	22.1	280	11.3	83	104	—	8.8	1.6	180	423	8.35	384	356	356	—
15	2400	18.5	280	9.9	83	104	—	8.9	1.4	232	414	7.21	394	350	350	—
16	2400	14.7	286	8.8	83	104	—	9.4	1.1	294	393	6.43	365	307	316	—
17	2400	11.1	286	7.6	82	104	—	12.0	1.0	372	360	5.45	249	217	234	—
18	2400	7.4	286	6.4	81	104	—	12.2	0.9	440	218	4.54	252	136	158	—
19	2400	3.8	293	5.4	77	104	—	12.7	0.9	408	367	3.73	107	78	108	—
20	2400	—	293	4.2	75	104	—	12.7	0.8	304	460	2.74	61	41	69	—
21	700	—	87	1.2	74	104	—	1.2	0.1	144	309	2.40	137	117	149	—

ENGINE MERCEDES-BENZ OM636 DATE 1/9/73 WET BULB TEMP, °F 47

RUN 7 BAROMETER, in Hg 29.53 DRY BULB TEMP., °F 63

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	—	—	1.2	74	95	—	1.0	0.1	304	270	2.54	174	154	177	—
2	1700	—	—	2.9	70	99	—	[illegible]	0.5	228	246	2.53	92	71	99	—
3	1700	5.2	—	4.5	69	101	—	6.9	0.5	200	[illegible]	4.27	[illegible]	158	195	—
4	1700	10.4	—	5.8	68	102	—	6.4	0.6	266	358	5.87	303	255	[illegible]	—
5	1700	15.6	—	[illegible]	68	103	—	6.0	0.8	170	256	7.88	382	334	345	—
6	1700	20.8	—	10.4	70	104	—	5.9	0.9	150	1206	10.41	338	311	311	—
7	700	—	—	1.2	72	106	—	2.0	0.1	96	472	2.73	209	191	203	—
8	[illegible]	26.2	—	14.2	70	110	—	0.7	1.4	149	1526	10.47	369	324	327	—
9	2100	19.7	—	10.7	74	110	—	8.2	1.3	130	314	8.24	[illegible]	[illegible]	326	—
10	2100	13.1	—	[illegible]	76	110	—	8.0	1.2	185	[illegible]	[illegible]	[illegible]	[illegible]	258	—
11	2100	6.6	—	5.6	76	110	—	8.0	0.9	[illegible]	389	4.40	170	165	174	—
12	2100	—	—	3.6	75	[illegible]	—	8.0	0.3	170	135	2.30	83	67	94	—
13	700	—	—	1.2	74	104	—	1.2	[illegible]	95	283	2.40	160	146	176	—

ENGINE MERCEDES-BENZ OM636 DATE 1/10/73 WET BULB TEMP, °F 47

MAPPING RUN M-1 BAROMETER, in Hg 29.46 DRY BULB TEMP, °F 61

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	700	—	—	1.2	79	92	—	0.9	0.1	95	445	2.04	199	159	187	—
2	1700	—	—	2.8	76	95	—	7.6	0.5	116	327	2.75	94	71	99	—
3	1700	5.2	—	4.6	74	95	—	6.7	0.5	220	913	4.46	188	141	170	—
4	1700	10.4	—	6.3	71	95	—	6.0	0.6	232	344	6.12	305	238	268	—
5	1700	15.6	—	8.1	72	96	—	5.8	0.8	150	254	8.12	388	323	328	—
6	1700	20.8	—	10.4	73	97	—	5.5	0.9	200	1734	10.66	355	297	300	—
7	700	—	—	0.9	73	98	—	1.2	0.1	88	294	2.78	250	202	211	—
8	2100	26.2	—	14.2	74	100	—	9.8	1.4	174	1801	10.53	347	270	278	—
9	2100	19.7	—	10.6	77	100	—	8.8	1.3	130	265	8.52	366	302	303	—
10	2100	13.1	—	8.1	79	100	—	8.3	1.2	194	330	6.72	280	225	227	—
11	2100	6.6	—	5.6	78	101	—	8.0	1.0	512	364	4.42	182	145	152	—
12	2100	—	—	2.4	77	103	—	8.0	0.9	188	307	2.68	83	58	75	—
13	700	—	—	1.4	75	103	—	1.2	0.1	120	195	2.69	261	122	142	—

ENGINE MERCEDES-BENZ OM636 DATE 1/10/73 WET BULB TEMP., °F 49

MAPPING RUN M-2 BAROMETER, in Hg 29.40 DRY BULB TEMP., °F 61

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	1500	—	—	1.17	72	72	290	1.0	0.2	395	990	2.71	79	81	159	16.0
2	1800	—	—	1.44	73	74	300	1.5	0.1	450	1296	2.59	66	62	138	15.9
3	1800	1.34	—	1.94	73	82	360	1.5	0.1	425	644	3.41	189	184	260	14.7
4	1800	2.67	—	2.49	74	84	420	1.4	0.1	425	460	4.22	385	359	431	13.5
5	1800	3.99	—	2.74	74	84	490	1.2	0.1	350	308	4.98	539	497	572	12.1
6	1800	5.32	—	3.21	74	88	550	1.0	0.1	298	284	5.66	627	578	625	10.7
7	1800	6.67	—	3.55	74	90	660	1.0	0.2	264	280	6.76	570	617	645	9.1
8	1800	8.01	—	4.10	74	90	770	1.0	0.2	265	354	7.71	564	600	624	7.4
9	1800	9.33	—	4.62	74	94	910	1.0	0.3	292	437	8.82	471	524	524	5.6
10	1800	10.6	—	5.53	74	95	1080	1.0	0.3	326	1156	10.26	360	400	418	3.0
11	1500	—	—	1.14	74	95	400	1.0	0.2	236	863	2.45	107	123	202	15.6
12	2400	13.2	—	8.10	68	75	1230	2.0	0.3	400	753	10.77	387	345	349	3.3
13	2400	11.6	—	5.95	74	83	1030	1.7	0.3	258	251	9.29	499	442	443	6.2
14	2400	9.91	—	5.44	76	91	870	2.0	0.2	270	277	7.79	507	447	469	7.8
15	2400	8.26	—	4.76	76	96	760	1.9	0.2	269	311	6.78	526	456	496	9.2
16	2400	6.62	—	4.44	76	96	670	2.0	0.15	333	349	6.09	470	401	446	10.9
17	2400	4.97	—	3.81	76	97	610	2.1	0.15	264	397	5.32	419	300	409	11.7
18	2400	3.31	—	3.23	76	103	520	2.0	0.15	410	482	4.47	316	299	322	12.9
19	2400	1.65	—	2.80	76	100	450	2.2	0.15	528	534	3.70	202	157	229	13.9
20	2400	—	—	2.16	76	100	370	2.4	0.15	655	1092	2.86	106	75	140	15.3
21	1500	—	—	1.24	76	100	280	1.0	0.2	550	862	2.60	148	104	183	15.6

ENGINE ONAN DJBA DATE 11/1/72 WET BULB TEMP, °F 58

RUN 2 BAROMETER, in Hg 29.18 DRY BULB TEMP, °F 70

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F: INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS: INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	1500	———	———	1.16	73	68	310	1.0	0.2	325	873	2.65	127	108	188	16.0
2	1800	———	———	1.41	73	76	300	1.4	0.1	426	1149	2.55	100	79	156	16.0
3	1800	1.36	———	2.17	74	82	370	1.5	0.1	366	500	3.47	246	239	281	14.7
4	1800	2.73	———	2.38	74	85	430	1.2	0.1	366	311	4.11	393	397	455	13.6
5	1800	4.09	———	2.81	74	88	500	1.2	0.1	312	353	4.92	549	526	609	12.4
6	1800	5.45	———	3.21	74	90	580	1.1	0.2	305	292	6.30	622	555	636	10.7
7	1800	6.81	———	3.75	74	94	670	1.1	0.2	293	281	6.60	697	586	625	9.0
8	1800	8.18	———	4.62	74	96	790	1.0	0.3	324	278	7.54	597	543	557	7.5
9	1800	9.55	———	4.38	75	98	950	1.0	0.3	373	438	8.74	510	461	469	5.6
10	1800	10.5	———	5.83	75	101	1080	1.0	0.5	400	902	10.07	384	389	408	3.3
11	1500	———	———	1.09	75	102	380	1.0	0.2	201	813	2.25	73	114	186	15.7
12	2400	12.2	———	7.18	76	99	1040	1.8	0.2	320	252	8.83	448	422	425	5.6
13	2400	11.7	———	5.86	76	103	1010	1.7	0.2	230	254	8.13	483	424	438	6.4
14	2400	9.98	———	5.40	76	105	910	1.7	0.2	221	257	7.22	488	445	458	7.9
15	2400	8.30	———	4.83	77	88	770	2.0	0.2	230	247	6.60	491	429	463	9.2
16	2400	6.69	———	4.52	77	90	710	2.0	0.2	335	371	6.08	462	384	426	10.5
17	2400	4.97	———	3.74	77	93	610	2.1	0.2	352	399	5.12	405	328	378	12.0
18	2400	3.33	———	3.36	76	94	550	2.1	0.2	456	554	4.42	302	248	304	13.0
19	2400	1.66	———	2.71	75	103	460	2.4	0.2	472	692	3.58	203	145	213	14.3
20	2400	———	———	2.19	75	98	370	2.2	0.2	608	1106	2.81	106	72	134	15.6
21	1500	———	———	1.20	74	100	300	1.0	0.2	783	737	2.49	142	97	173	16.0

ENGINE ONAN DJEA   DATE 11/2/72   WET BULB TEMP, °F 58

RUN 3   BAROMETER, in Hg 29.15   DRY BULB TEMP., °F 72

C-43

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	1500	———	———	1.13	73	74	330	1.0	0.2	256	848	2.59	120	96	159	16.1
2	1800	———	———	1.62	74	78	310	1.5	0.1	359	1182	2.80	113	73	143	15.7
3	1800	1.34	———	2.01	74	80	350	1.4	0.1	280	509	3.46	245	214	281	14.5
4	1800	2.66	———	2.32	75	82	420	1.2	0.1	325	343	4.34	406	309	414	13.4
5	1800	3.99	———	2.66	75	87	490	1.2	0.1	298	295	5.03	561	486	542	12.0
6	1800	5.32	———	3.26	75	89	560	1.1	0.2	302	282	5.86	615	547	603	10.7
7	1800	6.65	———	3.55	75	93	650	1.0	0.2	278	257	6.58	576	588	616	9.4
8	1800	7.97	———	4.23	75	96	760	1.0	0.3	301	287	7.69	546	523	559	7.6
9	1800	9.31	———	4.76	75	97	880	1.0	0.3	285	338	8.54	479	486	508	6.0
10	1800	10.7	———	5.60	75	97	1100	1.0	0.4	450	1040	10.44	323	389	392	3.1
11	1500	———	———	1.03	75	100	320	1.0	0.2	248	823	2.39	107	133	185	15.7
12	2400	12.1	———	7.25	75	88	1110	1.5	0.3	256	418	10.45	338	399	399	4.4
13	2400	11.2	———	6.05	76	87	1010	1.7	0.3	226	250	9.36	377	430	430	6.1
14	2400	9.60	———	5.39	76	95	870	1.8	0.3	185	298	7.77	490	436	458	7.9
15	2400	7.95	———	4.86	75	97	760	1.9	0.3	191	301	6.74	584	439	482	9.4
16	2400	6.38	———	4.19	75	98	670	2.0	0.2	262	348	5.86	408	371	415	10.6
17	2400	4.78	———	3.74	75	100	540	2.0	0.2	269	419	5.03	343	319	367	11.8
18	2400	3.19	———	3.27	75	102	540	2.0	0.2	309	492	4.40	264	247	308	12.7
19	2400	1.58	———	2.53	75	103	460	2.2	0.2	458	664	3.69	146	152	213	13.8
20	2400	———	———	2.29	75	102	390	2.3	0.2	585	1021	3.01	66	82	145	14.7
21	1500	———	———	1.20	75	100	270	1.0	0.2	562	1041	2.49	66	81	153	15.6

ENGINE ONAN DJBA DATE 11/15/72 WET BULB TEMP., °F 62

RUN 4 BAROMETER, in Hg 29.24 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	1500	—		1.23	75	80	200	1.0	0.2	525	913	2.83	119	81	155	15.8
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	1500	2.14	—	2.01	76	84	370	1.0	0.2	464	328	4.49	465	410	466	13.2
4	1500	4.26	—	2.74	77	84	490	1.0	0.2	362	400	6.31	615	567	640	10.3
5	1500	6.43	—	3.30	77	84	670	0.9	0.2	329	698	8.13	652	595	635	7.6
6	1500	8.79	—	4.85	75	85	1040	0.7	0.3	774	2730	11.62	393	338	347	2.4
7	1500	—	—	1.12	76	88	200	1.0	0.2	482	1095	2.68	133	97	176	15.4
8	2100	12.1	—	6.66	73	82	850	1.5	0.4	450	861	10.78	333	335	344	3.2
9	2100	8.70	—	4.72	73	88	800	1.5	0.3	232	256	7.30	512	475	504	8.5
10	2100	5.81	—	3.48	73	94	660	1.5	0.3	295	314	5.33	429	409	444	11.5
11	2100	2.90	—	2.63	74	94	500	1.7	0.2	188	399	3.89	264	241	284	13.8
12	2100	—	—	1.81	74	97	360	1.8	0.2	482	1255	2.62	92	65	124	15.6
13	1500	—	—	1.27	74	98	290	1.2	0.2	347	941	2.57	119	90	159	15.7

ENGINE ONAN DJBA DATE 10/30/72 WET BULB TEMP., °F 68

MAPPING RUN M-1 BAROMETER, in Hg 29.02 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	1500	—	—	1.19	77	82	270	1.0	0.1	307	848	2.71	148	89	158	16.8
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
3	1500	2.16	—	1.86	77	85	380	1.0	0.1	340	230	4.41	534	448	505	14.1
4	1500	4.56	—	2.69	77	88	540	1.0	0.15	170	239	5.59	747	818	678	11.5
5	1500	6.72	—	3.65	77	88	720	0.9	0.2	165	300	7.38	778	641	675	8.7
6	1500	8.79	—	4.76	77	92	1000	0.8	0.3	487	1296	10.25	403	391	394	4.0
7	1500	—	—	1.08	77	92	360	1.0	0.2	210	712	2.49	155	128	208	16.5
8	2100	11.7	—	6.05	77	94	990	1.3	0.3	197	283	9.30	538	474	485	5.6
9	2100	9.22	—	4.69	77	94	830	1.5	0.2	159	267	7.31	599	555	566	8.2
10	2100	6.15	—	3.96	77	98	620	1.9	0.2	196	307	5.32	482	467	503	11.0
11	2100	3.08	—	2.91	78	98	500	1.6	0.2	220	380	3.81	304	302	369	13.8
12	2100	—	—	1.92	78	99	370	1.7	0.1	457	1082	2.55	107	88	160	16.0
13	1500	—	—	1.15	98	100	300	1.0	0.1	352	941	2.34	114	96	169	16.4

ENGINE ONAN DJBA

MAPPING RUN M-2

DATE 11/2/72

BAROMETER, in Hg 29.13

WET BULB TEMP, °F 59

DRY BULB TEMP, °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	1000	——	——	0.95	78	79	240	0.5	0.1	450	740	2.73	217	165	230	16.4
2	1500	——	——	1.16	78	80	330	1.0	0.2	385	915	2.68	119	77	149	16.4
3	1500	1.91	——	1.88	79	83	330	0.9	0.2	358	444	4.07	359	312	380	14.1
4	1500	3.84	——	2.32	79	85	470	0.9	0.2	258	271	5.13	590	547	627	12.2
5	1500	5.75	——	5.97	79	87	620	0.8	0.2	262	343	6.69	647	608	646	9.7
6	1500	7.67	——	3.79	79	92	850	0.9	0.2	304	424	8.30	562	519	522	6.9
7	1000	——	——	0.90	79	92	250	0.5	0.1	348	767	2.42	93	122	175	16.8
8	2100	12.8	——	6.64	79	95	1180	1.5	0.4	450	1486	10.36	266	350	357	2.9
9	2100	9.58	——	4.86	79	95	930	1.4	0.4	220	251	8.35	523	474	449	7.3
10	2100	6.40	——	3.62	79	97	710	1.5	0.3	252	313	5.67	497	433	462	11.0
11	2100	3.18	——	2.87	79	99	610	1.6	0.2	900	800	4.24	227	207	229	13.5
12	2100	——	——	1.81	79	104	380	1.8	0.2	1590	895	2.74	136	126	165	16.3
13	1000	——	——	0.83	79	106	280	0.5	0.1	340	706	2.38	175	137	191	16.5

ENGINE ONAN DJBA   DATE 11/6/72   WET BULB TEMP., °F 68

MAPPING RUN M-3   BAROMETER, in Hg 29.04   DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	1000	———	———	0.81	76	82	270	0.5	0.1	251	601	2.49	205	185	253	16.3
2	1500	———	———	1.32	77	73	290	1.0	0.2	305	737	2.66	135	123	195	13.3
3	1500	2.06	———	1.83	77	75	380	1.0	0.2	240	278	3.94	402	380	433	14.0
4	1500	4.09	———	2.48	77	78	500	0.8	0.2	198	307	5.47	579	629	632	11.4
5	1500	6.15	———	3.43	77	81	650	0.8	0.2	160	358	6.17	670	655	693	9.3
6	1500	8.16	———	4.00	77	87	880	0.8	0.2	210	612	8.32	513	530	537	6.2
7	1000	———	———	0.77	76	91	300	0.5	0.1	225	651	2.30	191	180	224	16.3
8	2100	11.2	———	5.91	78	90	1050	1.3	0.4	220	283	9.41	447	462	466	5.2
9	2100	6.44	———	3.75	78	100	730	1.4	0.3	169	272	5.74	512	489	517	10.8
10	2100	4.29	———	2.93	78	102	590	1.5	0.3	168	310	4.55	392	383	428	12.9
11	2100	2.16	———	2.54	78	103	460	1.6	0.2	222	500	3.53	246	218	272	14.5
12	2100	———	———	1.96	78	104	360	1.8	0.2	372	1163	2.60	107	85	125	15.8
13	1000	———	———	0.81	77	90	270	0.5	0.1	192	651	2.40	176	154	214	16.1

ENGINE ONAN DJBA   DATE 11/8/72   WET BULB TEMP., °F 57

MAPPING RUN M-4   BAROMETER, in Hg 29.30   DRY BULB TEMP., °F 74

MODE	ENGINE SPEED RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	600	—	157	0.7	91	79	290	2.0	0.09	280	183	1.18	92	62	74	—
2	1450	—	385	3.5	87	79	265	11.0	0.22	238	245	1.31	101	67	84	—
3	1450	6.9	385	4.2	87	79	336	11.0	0.22	194	268	2.10	178	158	177	—
4	1450	13.0	382	6.0	89	79	425	10.5	0.26	176	313	3.09	330	313	337	—
5	1450	19.6	377	6.9	90	80	510	10.5	0.36	152	250	4.08	561	555	583	—
6	1450	25.7	375	9.6	90	81	606	10.5	0.51	140	188	5.14	808	814	837	—
7	1450	33.0	371	12.2	91	81	738	10.5	0.57	138	150	6.45	1188	1196	1224	—
8	1450	39.5	364	13.9	94	83	834	10.3	0.65	132	171	7.45	1480	1483	1510	—
9	1450	45.3	361	17.2	97	84	1044	10.0	0.67	112	649	9.35	1831	1757	1810	—
10	1450	50.4	357	20.6	100	84	1170	10.0	0.65	78	4565	10.38	1803	1652	1704	—
11	600	—	154	0.5	97	85	307	2.0	0.07	252	221	1.18	131	78	84	—
12	2400	75.6	580	30.2	96	85	1239	19.5	1.50	38	3365	9.99	1875	1779	1793	—
13	2400	66.6	575	25.6	99	86	1087	19.5	1.32	86	740	8.70	1824	1838	1865	—
14	2400	57.0	575	21.3	99	86	935	19.5	1.17	78	219	7.38	1536	1512	1539	—
15	2400	46.8	577	17.7	98	86	808	19.5	1.08	108	210	6.12	1023	979	1007	—
16	2400	37.8	579	15.5	97	86	717	20.0	1.00	132	259	5.33	765	709	723	—
17	2400	28.2	580	12.5	96	86	621	20.0	0.94	146	322	4.41	524	431	449	—
18	2400	18.6	579	10.2	97	87	538	20.0	0.86	180	350	3.55	338	264	279	—
19	2400	9.6	580	8.1	96	87	456	20.0	0.83	238	340	2.70	216	154	172	—
20	2400	—	580	5.5	96	87	333	20.0	0.85	328	331	1.90	139	83	100	—
21	600	—	146	0.5	96	87	256	2.0	0.62	324	258	1.11	102	68	74	—

ENGINE PERKINS 4.236 DATE 10/11/72 WET BULB TEMP., °F 67

RUN 1 BAROMETER, in Hg 29.38 DRY BULB TEMP., °F 75

	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F			RESTRICTIONS		FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
MODE					INTAKE AIR	FUEL	EXHAUST	INTAKE in H_2O	EXHAUST in Hg							
1	600	—	156	0.8	93	87	276	2.5	0.02	320	309	1.19	64	68	86	—
2	1450	—	377	2.7	93	86	258	11.0	0.24	250	283	1.32	83	74	80	—
3	1450	6.5	381	4.2	90	86	337	11.0	0.26	206	305	2.30	179	175	202	—
4	1450	13.4	406	6.0	93	86	429	11.0	0.28	192	327	3.30	330	342	380	—
5	1450	19.2	377	7.4	93	87	507	10.5	0.32	178	263	4.09	504	532	579	—
6	1450	26.5	369	9.6	93	87	616	10.5	0.50	166	187	5.33	806	868	896	—
7	1450	32.6	368	11.1	94	87	728	10.5	0.59	152	162	6.46	1175	1199	1227	—
8	1450	39.2	364	13.9	97	87	846	10.5	0.66	130	218	7.73	1627	1576	1631	—
9	1450	45.7	361	17.0	93	87	1012	10.5	0.64	134	1001	9.17	1966	1791	1858	—
10	1450	50.8	359	20.0	94	87	1153	10.0	0.68	100	4755	10.27	1893	1684	1723	—
11	600	—	163	0.6	95	87	288	2.5	0.04	264	271	1.25	151	87	95	—
12	2400	75.0	577	30.0	98	88	1236	19.5	1.42	50	3304	9.96	1925	1720	1773	—
13	2400	66.6	571	24.2	101	89	1074	19.5	1.32	78	610	8.65	1630	1803	1870	—
14	2400	57.0	571	21.6	101	90	961	19.5	1.19	70	261	7.50	1611	1520	1574	—
15	2400	47.4	569	18.3	102	92	827	19.5	1.07	100	245	6.40	1145	1076	1118	—
16	2400	37.8	571	14.5	101	92	715	19.5	0.99	128	259	5.34	793	710	724	—
17	2400	28.2	571	12.2	101	92	624	20.0	0.94	132	323	4.55	537	450	469	—
18	2400	19.2	573	9.4	100	92	544	20.0	0.87	170	350	3.62	832	234	293	—
19	2400	9.6	577	6.3	98	92	459	20.0	0.85	226	328	2.77	217	162	181	—
20	2400	—	579	2.5	97	92	389	20.0	0.86	292	294	2.04	140	92	108	—
21	600	—	146	0.4	97	92	251	2.0	0.02	288	246	1.19	102	68	89	—

ENGINE PERKINS 4.236 DATE 10/11/72 WET BULB TEMP, °F 64

RUN 2 BAROMETER, in Hg 29.37 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	640	———	159	1.0	87	78	373	2.0	0.07	316	258	1.32	83	90	97	———
2	1450	———	388	2.8	84	78	273	11.0	0.29	228	270	1.45	83	84	102	———
3	1450	6.9	389	4.7	83	79	341	10.5	0.29	224	330	2.30	198	181	217	———
4	1450	12.7	394	5.9	83	79	412	10.8	0.31	222	351	3.17	298	328	366	———
5	1450	20.3	380	8.0	84	79	518	10.4	0.37	200	262	4.29	538	583	620	———
6	1450	26.5	376	9.8	84	79	611	10.5	0.51	209	200	5.27	821	847	898	———
7	1450	32.6	374	12.3	85	79	736	10.6	0.60	148	173	6.61	1206	1115	1170	———
8	1450	39.5	373	14.3	85	80	850	10.5	0.62	148	207	7.66	1534	1551	1632	———
9	1450	45.7	369	17.0	86	80	982	10.3	0.61	184	532	8.98	1760	1782	1836	———
10	1450	51.5	368	20.2	87	80	1150	10.2	0.63	100	4687	10.40	1910	1733	1785	———
11	640	———	166	0.8	90	80	293	2.0	0.08	272	284	1.18	121	82	90	———
12	2400	76.2	575	30.9	88	81	1220	19.8	1.38	60	2957	10.15	1985	1755	1794	———
13	2400	66.6	592	25.3	93	81	1079	19.3	1.34	132	656	8.59	1851	1803	1884	———
14	2400	57.6	594	21.8	89	81	953	19.3	1.25	90	242	7.32	1503	1242	1255	———
15	2400	48.0	594	18.4	89	82	825	19.0	1.15	98	233	6.34	1142	883	910	———
16	2400	39.0	592	15.5	90	82	719	19.0	1.09	142	283	5.34	807	618	637	———
17	2400	28.8	598	13.0	87	82	622	20.0	1.03	146	372	4.42	526	371	376	———
18	2400	19.8	598	10.4	87	81	534	20.5	0.96	184	401	3.36	340	226	237	———
19	2400	9.6	598	8.0	87	81	447	20.0	0.88	240	379	2.71	218	134	145	———
20	2400	———	600	5.8	86	81	386	20.4	0.87	308	331	1.91	140	78	90	———
21	640	———	151	0.8	86	81	238	1.7	0.05	304	296	1.12	102	52	70	———

ENGINE PERKINS 4.236 DATE 10/13/72 WET BULB TEMP., °F 64

RUN 3 BAROMETER, in Hg 29.34 DRY BULB TEMP., °F 73

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	TEMPERATURE, °F FUEL	TEMPERATURE, °F EXHAUST	RESTRICTIONS INTAKE in H_2O	RESTRICTIONS EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	640	—	160	0.9	86	81	293	2.0	0.09	320	246	1.25	102	86	93	—
2	1450	—	388	2.5	88	82	262	11.0	0.26	260	234	1.46	92	73	89	—
3	1450	6.9	383	4.2	88	82	335	10.5	0.31	188	256	2.18	198	160	185	—
4	1450	13.1	383	5.5	88	82	434	10.5	0.34	196	291	3.24	385	323	348	—
5	1450	19.6	374	7.8	92	82	548	10.5	0.35	194	227	4.30	661	575	622	—
6	1450	26.1	374	9.8	92	83	610	10.5	0.44	202	153	5.29	949	872	890	—
7	1450	33.0	370	10.7	92	83	728	10.5	0.54	194	127	6.48	1308	1187	1215	—
8	1450	39.5	370	14.1	92	84	839	10.5	0.57	146	160	7.68	1671	1499	1568	—
9	1450	46.0	364	15.0	92	84	992	10.5	0.65	182	544	9.20	1993	1755	1822	—
10	1450	51.1	361	20.6	97	85	1165	10.5	0.66	156	4685	10.61	1952	1666	1679	—
11	640	—	157	0.7	98	85	287	2.0	0.07	240	209	1.19	122	80	85	—
12	2400	75.0	583	30.4	95	86	1245	19.5	1.37	32	2840	10.30	1986	1690	1756	—
13	2400	66.3	571	25.[illegible]	101	86	1082	19.5	1.26	124	644	8.80	2019	1706	1819	—
14	2400	58.2	577	22.6	98	86	975	19.5	1.18	86	241	7.82	1769	1559	1573	—
15	2400	48.0	574	18.5	100	86	844	19.5	1.10	130	233	6.48	1193	1036	1063	—
16	2400	39.0	571	15.3	101	87	720	19.5	1.06	166	272	5.42	822	745	759	—
17	2400	28.8	577	13.0	98	87	644	20.0	0.97	160	385	4.56	549	465	470	—
18	2400	19.2	577	10.6	98	87	555	20.0	0.91	198	401	3.63	350	285	299	—
19	2400	10.2	580	7.9	96	87	468	20.0	0.87	240	366	2.84	228	174	189	—
20	2400	—	579	5.4	97	87	394	20.5	0.85	318	332	2.04	140	101	116	—
21	640	—	150	0.8	96	87	247	2.5	0.04	330	284	1.19	92	70	91	—

ENGINE PERKINS 4.236　　DATE 10/13/72　　WET BULB TEMP, °F 61

RUN 4　　BAROMETER, in Hg 29.28　　DRY BULB TEMP., °F 70

	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F			RESTRICTIONS		FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
MODE					INTAKE AIR	FUEL	EXHAUST	INTAKE in H_2O	EXHAUST in Hg							
1	640	——	152	1.0	80	79	214	2.0	0.05	320	270	1.25	64	68	93	——
2	1450	——	391	2.8	80	79	259	11.5	0.27	302	281	1.51	73	78	101	——
3	1450	6.5	395	4.8	80	79	341	11.5	0.30	276	329	2.43	167	176	214	——
4	1450	13.4	384	6.5	82	79	434	11.0	0.32	272	334	3.45	324	369	407	——
5	1450	19.2	405	8.4	84	79	510	11.0	0.37	266	273	4.33	535	655	702	——
6	1450	26.5	373	11.0	84	79	632	11.1	0.51	260	163	5.52	871	999	1027	——
7	1450	32.3	373	13.5	84	79	728	11.0	0.60	254	150	6.59	1155	1359	1400	——
8	1450	38.1	340	15.1	84	80	857	10.9	0.65	150	240	7.96	1599	1676	1770	——
9	1450	45.7	338	18.1	85	80	1024	11.0	0.67	216	1252	9.40	1845	1830	1896	——
10	1450	50.4	374	20.5	87	80	1161	10.9	0.63	148	5133	10.50	1818	1738	1790	——
11	640	——	154	0.8	86	80	227	2.0	0.07	250	244	1.31	111	81	93	——
12	2400	76.2	575	30.4	86	80	1213	21.0	1.38	60	3213	10.12	1769	1763	1829	——
13	2400	66.6	583	25.0	93	81	1063	20.8	1.32	150	509	8.55	1722	1837	1918	——
14	2400	57.6	580	21.5	94	81	947	21.0	1.24	94	207	7.44	1407	1468	1536	——
15	2400	48.0	588	18.7	90	80	836	21.0	1.18	110	221	6.59	1108	1167	1208	——
16	2400	39.0	590	15.9	89	80	727	21.5	1.10	152	282	5.52	749	753	776	——
17	2400	28.8	592	13.9	83	81	629	22.0	1.03	164	349	4.72	492	481	500	——
18	2400	19.2	592	10.2	88	81	531	21.5	0.96	198	362	3.61	306	283	297	——
19	2400	9.6	594	8.1	87	81	449	21.5	0.90	260	340	2.76	196	171	194	——
20	2400	——	596	5.8	86	81	386	21.5	0.88	320	330	2.17	129	100	121	——
21	640	——	151	1.0	84	80	234	2.0	0.04	324	308	1.25	92	72	96	——

ENGINE PERKINS 4.236 DATE 10/18/72 WET BULB TEMP., °F 68

RUN 5 BAROMETER, in Hg 29.19 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	600	—	151	0.8	84	80	205	2.0	0.03	316	258	0.99	64	58	81	—
2	1450	—	390	2.6	84	80	254	11.5	0.27	298	270	1.31	64	61	84	—
3	1450	6.9	386	4.4	84	80	346	11.4	0.29	272	329	2.23	167	184	215	—
4	1450	12.7	387	6.0	83	80	418	11.3	0.34	262	338	3.08	297	322	356	—
5	1450	18.8	380	7.8	85	80	513	11.0	0.38	254	262	4.01	514	582	634	—
6	1450	26.5	376	10.9	85	80	620	11.0	0.53	256	187	5.20	806	877	960	—
7	1450	33.0	371	13.7	86	80	749	11.0	0.61	246	173	6.44	1234	1194	1318	—
8	1450	38.8	368	15.6	88	80	859	11.2	0.71	192	298	7.89	1676	1568	1635	—
9	1450	45.7	366	17.5	90	81	1021	11.0	0.73	254	1202	9.20	1912	1675	1754	—
10	1450	50.0	355	20.7	92	81	1165	10.8	0.68	196	5251	10.35	1880	1568	1607	—
11	600	—	162	0.6	87	81	232	2.0	0.59	232	245	1.04	121	73	77	—
12	2400	75.6	577	30.5	85	81	1216	21.0	1.40	62	1810	10.12	1914	1592	1658	—
13	2400	67.2	556	25.7	96	81	1097	21.0	1.27	160	787	8.74	1901	1711	1804	—
14	2400	58.2	562	22.1	93	82	963	21.0	1.21	108	227	7.36	1553	1398	1492	—
15	2400	48.0	580	18.5	94	82	833	21.0	1.16	122	209	6.37	1140	1031	1085	—
16	2400	37.8	580	16.0	94	82	726	21.5	1.09	150	258	5.38	803	694	722	—
17	2400	28.2	588	12.8	90	82	619	21.5	1.03	168	334	4.27	501	421	435	—
18	2400	19.2	590	10.6	89	83	543	21.5	0.95	208	373	3.54	348	273	297	—
19	2400	9.6	594	7.8	87	84	452	21.8	0.91	270	340	2.63	216	154	174	—
20	2400	—	594	5.6	87	84	352	22.0	0.88	310	306	1.83	139	88	96	—
21	600	—	151	0.8	85	83	234	2.0	0.04	314	270	0.99	92	58	78	—

ENGINE PERKINS 4.236　　DATE 10/18/72　　WET BULB TEMP., °F 68

RUN 6　　BAROMETER, in Hg 29.18　　DRY BULB TEMP., °F 75

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	605	—	—	0.8	86	85	238	2.0	0.04	302	245	1.19	64	61	81	—
2	1700	—	—	3.4	88	85	290	14.0	0.44	302	270	1.45	83	73	93	—
3	1700	14.4	—	6.8	87	85	417	13.9	0.46	270	315	3.09	330	309	347	—
4	1700	28.9	—	11.2	90	86	639	13.5	0.51	234	163	5.27	847	813	859	—
5	1700	42.9	—	15.8	94	86	839	13.4	0.55	246	149	7.45	1611	1524	1633	—
6	605	57.8	—	23.1	98	87	1171	12.8	0.85	148	5147	10.38	1843	1545	1598	—
7	2100	—	—	0.5	100	88	269	2.0	0.04	248	183	1.11	111	78	87	—
8	2100	68.8	—	27.6	91	88	1199	17.0	1.06	116	3541	10.52	2060	1795	1808	—
9	2100	51.4	—	19.0	95	88	943	17.3	0.94	270	183	7.71	1783	1587	1655	—
10	2100	33.6	—	13.0	93	87	707	17.0	0.88	348	307	5.33	916	816	844	—
11	2100	16.8	—	8.7	93	87	521	17.5	0.76	352	301	3.49	393	317	435	—
12	2100	—	—	4.6	88	87	338	17.8	0.69	360	256	1.77	149	101	123	—
13	605	—	—	0.7	88	87	232	2.0	0.03	360	208	1.11	102	67	90	—

ENGINE PERKINS 4.236 DATE 10/18/72 WET BULB TEMP, °F 66

MAPPING RUN M-1 BAROMETER, in Hg 29.14 DRY BULB TEMP, °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	605	—	—	0.6	92	88	238	2.0	0.03	360	258	1.24	64	67	90	—
2	1700	—	—	3.7	88	88	290	13.9	0.47	372	307	1.58	64	73	98	—
3	1700	14.0	—	6.7	85	88	417	13.7	0.45	316	338	3.35	349	336	383	—
4	1700	28.9	—	11.0	87	88	639	13.5	0.51	294	187	540	916	891	933	—
5	1700	42.5	—	15.8	87	88	839	13.0	0.57	304	171	7.59	1667	1564	1659	—
6	1700	58.2	—	22.8	89	89	1171	13.0	0.81	168	4277	10.44	1885	1590	1611	—
7	605	—	—	0.6	94	90	269	2.0	0.03	318	245	1.25	111	305	97	—
8	2100	68.2	—	27.6	88	89	1199	17.5	1.07	118	3615	10.52	2038	1729	1756	—
9	2100	50.9	—	18.6	94	89	943	17.0	0.97	180	125	7.51	1686	1537	1618	—
10	2100	34.1	—	12.8	92	89	907	17.5	0.87	210	212	5.21	848	800	814	—
11	2100	17.3	—	9.5	89	89	521	18.0	0.75	260	288	3.49	371	317	336	—
12	2100	—	—	4.2	57	39	338	18.0	0.69	360	256	1.84	130	112	127	—
13	605	—	—	0.7	88	90	232	2.0	0.03	368	234	1.18	83	66	84	—

ENGINE PERKINS 4.236 DATE 10/18/72 WET BULB TEMP, °F 65

MAPPING RUN M-2 BAROMETER, in Hg 29.12 DRY BULB TEMP, °F 73

MODE	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lb_m/hr	FUEL FLOW, lb_m/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
1	605	—	—	0.8	99	79	222	2.0	0.04	228	247	1.26	64	90	99	—
2	1700	—	—	3.4	86	79	292	13.9	0.44	230	271	1.53	64	89	108	—
3	1700	14.4	—	6.7	84	79	425	13.5	0.46	210	329	3.11	299	344	378	—
4	1700	23.9	—	11.2	84	79	629	13.7	0.51	206	213	5.24	786	884	926	—
5	1700	42.5	—	15.5	87	79	808	13.3	0.57	224	162	6.96	1480	1639	1680	—
6	1700	59.1	—	23.3	89	81	1167	13.0	0.86	188	5339	9.70	1786	1780	1833	—
7	605	—	—	0.7	95	81	316	2.3	0.07	236	235	1.12	93	103	108	—
8	2100	69.8	—	28.0	89	82	1179	17.3	1.07	108	3312	9.47	1944	1977	2070	—
9	2100	52.0	—	19.0	95	82	934	17.4	0.97	148	174	6.83	1575	1835	1959	—
10	2100	33.6	—	12.6	94	83	674	17.8	0.85	154	238	4.57	804	932	960	—
11	2100	17.3	—	8.4	93	83	505	18.0	0.81	188	292	2.91	248	364	388	—
12	2100	—	—	4.5	89	83	343	18.3	0.71	224	259	1.59	121	132	154	—
13	605	—	—	0.7	88	83	239	2.0	0.04	244	236	0.998	74	86	106	—

ENGINE PERKINS 4.236 DATE 10/19/72 WET BULB TEMP., °F 59

MAPPING RUN M-3 BAROMETER, in Hg 29.35 DRY BULB TEMP., °F 72

	ENGINE SPEED, RPM	OBSERVED POWER, hp	AIR FLOW, lbm/hr	FUEL FLOW, lbm/hr	TEMPERATURE, °F INTAKE AIR	FUEL	EXH-AUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	FIA HC, ppmC	NDIR CO, ppm	NDIR CO_2, %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	O_2, %
MODE																
1	605	—	—	0.7	83	81	241	2.0	0.04	234	197	1.19	74	80	94	—
2	1700	—	—	3.4	83	82	291	13.9	0.44	284	259	1.53	92	86	109	—
3	1700	14.4	—	7.0	83	82	436	13.5	0.46	232	291	3.31	396	382	425	—
4	1700	28.5	—	11.4	86	82	635	13.7	0.51	258	165	5.30	909	911	935	—
5	1700	42.9	—	15.7	87	82	832	13.3	0.57	276	126	7.50	1659	1698	1794	—
6	1700	58.6	—	23.0	89	82	1154	13.0	0.86	212	5011	10.23	2100	1691	1730	—
7	605	—	—	0.7	96	82	225	2.3	0.07	270	235	1.32	151	107	108	—
8	2100	68.2	—	27.6	90	83	1186	17.3	1.07	112	3348	10.46	2123	1942	1981	—
9	2100	50.9	—	18.7	97	84	933	17.4	0.97	166	115	7.56	1757	1724	1792	—
10	2100	33.1	—	12.8	97	84	691	17.8	0.85	174	177	5.17	911	857	912	—
11	2100	16.8	—	8.4	94	84	507	18.0	0.81	206	254	3.44	429	362	381	—
12	2100	—	—	4.2	93	84	341	18.3	0.71	230	209	1.78	190	131	151	—
13	605	—	—	0.3	90	84	234	2.0	0.04	244	197	1.19	132	80	102	—

ENGINE PERKINS 4.236 DATE 10/19/72 WET BULB TEMP., °F 59

MAPPING RUN M-4 BAROMETER, in Hg 29.34 DRY BULB TEMP., °F 72

APPENDIX D

COMPUTER-GENERATED DATA PRINTOUTS AND CALCULATION OF BRAKE SPECIFIC EMISSIONS FOR DIESEL ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

PROJECT' 11-2869-01　　DATE OF TEST' 11-28-72 TEST NO.1
ENGINE' AC 3500　　SERIAL NO.' 3D-17344

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	0.0	0.0	.05	6.04	6.09	.008
2	1500	1.8	.5	.09	10.51	10.60	.009
3	1500	54.3	15.5	.16	10.63	10.79	.016
4	1500	106.8	30.5	.24	11.00	11.24	.022
5	1500	157.6	45.0	.32	11.09	11.41	.029
6	1500	210.1	60.0	.42	11.47	11.89	.036
7	1500	262.6	75.0	.50	12.02	12.52	.042
8	1500	315.1	90.0	.61	12.77	13.38	.048
9	1500	367.6	105.0	.69	12.98	13.68	.054
10	1500	420.2	120.0	.80	13.21	14.01	.061
11	800	1.8	.3	.04	5.86	5.90	.007
12	2200	355.4	148.9	1.01	22.48	23.49	.045
13	2200	309.9	129.8	.87	21.14	22.01	.041
14	2200	264.4	110.7	.77	20.20	20.97	.038
15	2200	218.8	91.7	.65	19.09	19.75	.034
16	2200	176.8	74.1	.56	18.49	19.05	.030
17	2200	133.1	55.7	.45	17.34	17.79	.026
18	2200	87.5	36.7	.36	16.56	16.92	.022
19	2200	43.8	18.3	.26	15.68	15.94	.017
20	2200	1.8	.7	.18	19.92	20.10	.009
21	800	0.0	0.0	.04	5.85	5.89	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	240	801	216	0.00	R	R	R
2	188	571	255	.02	52.63	318.78	233.55
3	158	397	593	.68	1.45	7.28	17.83
4	188	316	912	1.34	.91	3.07	14.53
5	228	263	1206	1.98	.76	1.75	13.21
6	240	343	1467	2.64	.63	1.79	12.55
7	186	521	1688	3.30	.41	2.29	12.17
8	196	888	1908	3.96	.38	3.47	12.25
9	132	2376	2033	4.62	.23	8.14	11.44
10	56	4883	1915	5.28	.09	14.99	9.66
11	248	830	217	.02	72.45	483.12	207.21
12	122	715	1564	6.55	.25	2.97	10.66
13	150	400	1558	5.71	.34	1.78	11.42
14	148	306	1326	4.87	.37	1.52	10.84
15	148	272	1145	4.03	.42	1.54	10.66
16	156	262	951	3.26	.53	1.77	10.57
17	160	240	785	2.45	.67	2.01	10.83
18	170	254	596	1.61	1.04	3.09	11.89
19	156	270	413	.81	1.79	6.17	15.50
20	172	350	245	.03	62.23	252.67	289.97
21	300	899	179	0.00	R	R	R

CYCLE COMPOSITE　BSHC = .577 GRAM/BHP HR
BSCO+ = 4.908 GRAM/BHP HR
BSNO2++= 11.886 GRAM/BHP HR
BSHC + BSNO2++= 12.463 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 11-28-72 TEST NO.2
ENGINE' AC 3500 SERIAL NO.' 3D-17344

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	1.8	.3	.05	5.92	5.97	.008
2	1500	1.8	.5	.10	10.51	10.61	.009
3	1500	52.5	15.0	.16	10.73	10.89	.015
4	1500	105.0	30.0	.25	11.03	11.28	.022
5	1500	157.6	45.0	.33	11.21	11.54	.029
6	1500	210.1	60.0	.42	11.77	12.19	.035
7	1500	262.6	75.0	.51	12.21	12.72	.042
8	1500	315.1	90.0	.61	12.89	13.50	.047
9	1500	367.6	105.0	.72	13.60	14.32	.053
10	1500	416.7	119.0	.83	14.05	14.88	.059
11	800	1.8	.3	.04	5.73	5.77	.008
12	2200	360.6	151.1	1.02	23.16	24.18	.044
13	2200	315.1	132.0	.91	22.77	23.68	.040
14	2200	271.4	113.7	.79	21.42	22.21	.037
15	2200	225.8	94.6	.68	19.94	20.62	.034
16	2200	180.3	75.5	.58	18.96	19.54	.031
17	2200	134.8	56.5	.44	17.99	18.43	.025
18	2200	91.0	38.1	.37	17.04	17.41	.022
19	2200	45.5	19.1	.27	16.20	16.48	.017
20	2200	1.8	.7	.19	15.62	15.81	.012
21	800	1.8	.3	.04	5.73	5.77	.008

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	288	937	176	.02	85.08	551.80	170.51
2	240	624	245	.02	67.21	348.25	224.53
3	198	448	547	.66	1.90	8.55	17.15
4	214	341	867	1.32	1.06	3.37	14.08
5	254	275	1160	1.98	.86	1.85	12.85
6	256	320	1444	2.64	.69	1.71	12.67
7	248	533	1643	3.30	.56	2.38	12.04
8	220	825	1841	3.96	.44	3.25	11.93
9	114	2474	1990	4.62	.21	8.87	11.72
10	62	4262	1919	5.24	.10	14.02	10.36
11	192	693	276	.02	54.87	394.79	258.36
12	142	679	1560	6.65	.30	2.86	10.79
13	152	438	1500	5.81	.36	2.07	11.63
14	160	294	1301	5.00	.41	1.51	10.99
15	162	248	1148	4.16	.47	1.42	10.81
16	158	237	935	3.32	.54	1.62	10.45
17	172	229	756	2.48	.74	1.97	10.66
18	184	242	598	1.68	1.11	2.91	11.80
19	178	257	419	.84	2.03	5.84	15.64
20	186	297	243	.03	52.94	168.69	226.79
21	320	856	186	.02	91.45	487.32	174.02

CYCLE COMPOSITE BSHC = .629 GRAM/BHP HR
BSCO+ = 4.773 GRAM/BHP HR
BSNO2++= 11.913 GRAM/BHP HR
BSHC + BSNO2++= 12.542 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 11-28-72 TEST NO.3
ENGINE' AC 3500 SERIAL NO.' 3D-17344

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	0.0	0.0	.04	5.72	5.76	.008
2	1500	1.8	.5	.09	10.40	10.49	.009
3	1500	52.5	15.0	.16	10.71	10.87	.015
4	1500	105.0	30.0	.24	11.20	11.44	.022
5	1500	157.6	45.0	.32	11.21	11.53	.029
6	1500	210.1	60.0	.42	11.77	12.19	.036
7	1500	262.6	75.0	.51	11.97	12.48	.042
8	1500	315.1	90.0	.61	12.96	13.57	.047
9	1500	367.6	105.0	.71	13.26	13.97	.053
10	1500	414.9	118.5	.83	13.60	14.43	.061
11	800	1.8	.3	.04	5.54	5.58	.008
12	2200	357.1	149.6	1.01	23.15	24.16	.044
13	2200	315.1	132.0	.91	22.28	23.19	.041
14	2200	271.4	113.7	.80	21.37	22.17	.037
15	2200	225.8	94.6	.69	19.96	20.65	.035
16	2200	180.3	75.5	.57	18.83	19.40	.031
17	2200	134.8	56.5	.47	17.96	18.43	.026
18	2200	91.0	38.1	.37	16.92	17.29	.022
19	2200	45.5	19.1	.27	16.29	16.56	.017
20	2200	1.8	.7	.19	15.72	15.91	.012
21	800	1.8	.3	.04	5.72	5.76	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	272	842	175	0.00	R	R	R
2	224	612	194	.02	62.06	337.64	175.61
3	180	435	482	.66	1.72	8.30	15.10
4	196	341	730	1.32	.99	3.43	12.04
5	234	287	995	1.98	.79	1.94	11.01
6	232	307	1200	2.64	.62	1.64	10.53
7	224	496	1424	3.30	.49	2.17	10.24
8	206	788	1662	3.96	.41	3.12	10.82
9	142	2165	1792	4.62	.25	7.57	10.30
10	68	4469	1722	5.21	.11	14.31	9.06
11	212	560	280	.02	58.59	308.42	253.35
12	128	643	1404	6.58	.27	2.73	9.80
13	146	389	1362	5.81	.34	1.79	10.33
14	152	246	1195	5.00	.39	1.26	10.07
15	150	212	1025	4.16	.43	1.22	9.66
16	128	214	842	3.32	.43	1.45	9.35
17	160	204	699	2.48	.69	1.75	9.85
18	178	218	542	1.68	1.07	2.60	10.61
19	170	233	396	.84	1.95	5.32	14.84
20	178	272	230	.03	50.98	155.33	215.32
21	300	775	176	.02	85.54	440.27	163.94

CYCLE COMPOSITE BSHC = .590 GRAM/BHP HR
BSCO+ = 4.462 GRAM/BHP HR
BSNO2++= 10.603 GRAM/BHP HR
BSHC + BSNO2++= 11.194 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 11-28-72 TEST NO.4
ENGINE' AC 3500 SERIAL NO.' 3D-17344

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	0.0	0.0	.04	5.73	5.77	.008
2	1500	0.0	0.0	.09	10.40	10.49	.009
3	1500	52.5	15.0	.16	10.70	10.86	.015
4	1500	103.3	29.5	.23	10.84	11.07	.022
5	1500	154.1	44.0	.31	11.20	11.51	.028
6	1500	206.6	59.0	.41	11.76	12.17	.035
7	1500	259.1	74.0	.50	12.04	12.54	.041
8	1500	311.6	89.0	.59	12.64	13.23	.047
9	1500	362.4	103.5	.69	13.10	13.79	.053
10	1500	413.2	118.0	.82	13.87	14.69	.059
11	800	0.0	0.0	.04	5.54	5.58	.007
12	2200	355.4	148.9	1.00	23.14	24.14	.043
13	2200	311.6	130.5	.90	22.29	23.19	.040
14	2200	266.1	111.5	.78	21.38	22.16	.037
15	2200	220.6	92.4	.67	19.98	20.65	.034
16	2200	176.8	74.1	.57	18.86	19.43	.030
17	2200	133.1	55.7	.46	17.81	18.27	.026
18	2200	87.5	36.7	.37	17.15	17.52	.021
19	2200	43.8	18.3	.27	16.12	16.39	.017
20	2200	3.5	1.5	.19	15.57	15.76	.012
21	800	0.0	0.0	.04	5.72	5.76	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	268	966	197	0.00	R	R	R
2	224	652	247	0.00	R	R	R
3	186	474	562	.66	1.78	9.03	17.59
4	202	367	875	1.30	1.00	3.62	14.19
5	240	300	1188	1.94	.83	2.07	13.43
6	254	356	1420	2.60	.69	1.93	12.65
7	240	547	1638	3.26	.54	2.44	11.99
8	230	928	1837	3.92	.45	3.63	11.80
9	156	2273	2004	4.55	.27	7.96	11.54
10	92	4544	1909	5.19	.15	14.88	10.27
11	220	667	269	0.00	R	R	R
12	160	680	1592	6.55	.34	2.90	11.16
13	168	413	1510	5.74	.39	1.93	11.59
14	172	271	1329	4.90	.45	1.42	11.42
15	174	225	1158	4.07	.51	1.32	11.18
16	176	227	957	3.26	.61	1.56	10.85
17	184	216	786	2.45	.80	1.86	11.13
18	200	231	603	1.61	1.26	2.90	12.45
19	190	245	422	.81	2.24	5.75	16.31
20	192	285	245	.06	27.23	80.51	113.88
21	340	830	198	0.00	R	R	R

CYCLE COMPOSITE BSHC = .668 GRAM/BHP HR
BSCO+ = 4.817 GRAM/BHP HR
BSNO2++= 12.109 GRAM/BHP HR
BSHC + BSNO2++= 12.777 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 11-29-72 TEST NO.5
ENGINE' AC 3500 SERIAL NO.' 3D-17344

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	1.8	.3	.03	5.91	5.94	.006
2	1500	1.8	.5	.09	10.60	10.69	.009
3	1500	49.0	14.0	.16	10.82	10.98	.015
4	1500	105.0	30.0	.02	10.91	10.93	.002
5	1500	159.3	45.5	.32	11.28	11.60	.028
6	1500	210.1	60.0	.41	12.12	12.53	.034
7	1500	262.6	75.0	.60	12.28	12.88	.049
8	1500	316.9	90.5	.60	12.78	13.38	.047
9	1500	365.9	104.5	.71	13.51	14.22	.052
10	1500	421.9	120.5	.77	14.17	14.94	.055
11	800	5.3	.8	.04	5.72	5.76	.007
12	2200	348.4	145.9	.99	22.55	23.54	.044
13	2200	309.9	129.8	.77	21.83	22.60	.035
14	2200	266.1	111.5	.78	20.92	21.70	.037
15	2200	220.6	92.4	.67	19.92	20.59	.034
16	2200	176.8	74.1	.57	19.00	19.57	.030
17	2200	133.1	55.7	.46	17.83	18.29	.026
18	2200	87.5	36.7	.36	16.85	17.21	.021
19	2200	43.8	18.3	.26	15.95	16.21	.016
20	2200	5.3	2.2	.18	15.42	15.60	.012
21	800	0.0	0.0	.04	5.91	5.95	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	292	859	186	.02	85.90	503.63	179.50
2	224	559	253	.02	63.23	314.46	233.49
3	184	372	554	.62	1.90	7.67	18.75
4	204	291	900	1.32	.98	2.79	14.16
5	246	227	1135	2.00	.83	1.52	12.50
6	254	285	1394	2.64	.70	1.56	12.57
7	240	697	1536	3.30	.54	3.15	11.40
8	208	775	1791	3.98	.41	3.01	11.44
9	132	2022	1912	4.60	.24	7.24	11.24
10	54	4189	1881	5.30	.09	13.66	10.08
11	264	775	224	.05	25.10	146.71	69.60
12	142	519	1482	6.42	.30	2.20	10.33
13	152	368	1457	5.71	.35	1.69	10.96
14	152	234	1251	4.90	.39	1.20	10.52
15	156	213	1106	4.07	.46	1.25	10.65
16	160	202	902	3.26	.56	1.40	10.30
17	168	192	741	2.45	.73	1.65	10.51
18	182	206	557	1.61	1.13	2.54	11.30
19	178	221	409	.81	2.08	5.13	15.63
20	196	272	241	.10	18.35	50.80	73.92
21	332	857	177	0.00	R	R	R

CYCLE COMPOSITE BSHC = .631 GRAM/BHP HR
BSCO+ = 4.380 GRAM/BHP HR
BSNO2++= 11.525 GRAM/BHP HR
BSHC + BSNO2++= 12.156 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 11-29-72 TEST NO.6
ENGINE' AC 3500 SERIAL NO.' 3D-17344

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	0.0	0.0	.04	6.10	6.14	.007
2	1500	1.8	.5	.09	10.60	10.69	.009
3	1500	54.3	15.5	.17	10.81	10.98	.015
4	1500	105.0	30.0	.24	11.10	11.34	.022
5	1500	157.6	45.0	.32	11.38	11.70	.029
6	1500	210.1	60.0	.41	11.57	11.98	.035
7	1500	260.8	74.5	.50	12.03	12.53	.042
8	1500	315.1	90.0	.59	12.62	13.21	.047
9	1500	367.6	105.0	.71	13.67	14.38	.052
10	1500	416.7	119.0	.85	14.17	15.02	.060
11	800	1.8	.3	.05	5.53	5.58	.009
12	2200	341.4	143.0	.95	23.13	24.08	.041
13	2200	309.9	129.8	.89	22.26	23.15	.040
14	2200	266.1	111.5	.77	20.88	21.65	.037
15	2200	220.6	92.4	.66	19.63	20.29	.034
16	2200	178.6	74.8	.57	18.94	19.51	.030
17	2200	133.1	55.7	.46	17.89	18.35	.026
18	2200	87.5	36.7	.36	16.94	17.30	.021
19	2200	45.5	19.1	.26	16.11	16.37	.016
20	2200	5.3	2.2	.18	15.44	15.62	.012
21	800	5.3	.8	.04	5.91	5.95	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	268	870	168	0.00	R	R	R
2	216	625	215	.02	60.97	351.49	198.21
3	178	448	486	.68	1.66	8.34	14.88
4	198	341	827	1.32	.99	3.40	13.50
5	236	288	1106	1.98	.81	1.97	12.43
6	236	344	1358	2.64	.62	1.81	11.71
7	222	522	1547	3.28	.49	2.31	11.24
8	196	864	1774	3.96	.38	3.33	11.25
9	124	2507	1875	4.62	.22	9.03	11.09
10	50	4422	1781	5.24	.08	14.68	9.71
11	248	827	223	.02	68.50	455.00	201.95
12	128	621	1459	6.29	.28	2.75	10.62
13	144	413	1428	5.71	.34	1.94	11.00
14	146	294	1223	4.90	.37	1.50	10.27
15	148	272	1065	4.07	.43	1.57	10.10
16	152	250	878	3.29	.52	1.71	9.89
17	158	240	718	2.45	.69	2.08	10.21
18	172	255	559	1.61	1.07	3.16	11.39
19	166	282	390	.84	1.88	6.38	14.45
20	178	336	232	.10	16.69	62.72	71.17
21	316	884	168	.05	31.03	173.03	54.07

CYCLE COMPOSITE BSHC = .595 GRAM/BHP HR
BSCO+ = 4.940 GRAM/BHP HR
BSNO2++= 11.246 GRAM/BHP HR
BSHC + BSNO2++= 11.842 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT'11-2869-01 DATE OF TEST'2-1-72 TEST NO.1
ENGINE 'CAT D6C SERIAL NO.'1A4818

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	650	0.0	0.0	.06	7.60	7.66	.007
2	1400	0.0	0.0	.13	15.28	15.41	.009
3	1400	59.5	15.9	.20	15.93	16.13	.013
4	1400	117.3	31.3	.27	16.23	16.50	.016
5	1400	178.6	47.6	.34	16.52	16.86	.021
6	1400	236.3	63.0	.40	16.48	16.88	.024
7	1400	297.6	79.3	.51	16.75	17.26	.030
8	1400	353.6	94.3	.59	17.00	17.59	.035
9	1400	416.9	110.6	.68	17.45	18.13	.039
10	1400	479.7	127.9	.76	17.68	18.44	.043
11	650	0.0	0.0	.06	7.55	7.61	.008
12	1900	404.4	146.3	.97	25.65	26.62	.038
13	1900	353.6	127.9	.84	23.83	24.67	.035
14	1900	301.1	108.9	.73	22.60	23.33	.032
15	1900	253.8	91.8	.64	22.17	22.81	.029
16	1900	199.6	72.2	.52	20.87	21.39	.025
17	1900	148.8	53.8	.45	20.92	21.37	.021
18	1900	101.5	36.7	.39	19.52	19.91	.020
19	1900	50.8	18.4	.28	20.50	20.78	.014
20	1900	0.0	0.0	.22	20.57	20.79	.011
21	650	0.0	0.0	.05	7.60	7.65	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	26	252	54	0.00	R	R	R
2	24	278	62	0.00	R	R	R
3	6	157	146	.70	.08	4.20	6.41
4	4	103	271	1.38	.03	1.44	6.17
5	8	77	427	2.09	.04	.71	6.53
6	8	50	535	2.77	.03	.36	6.19
7	10	75	598	3.49	.03	.43	5.62
8	12	88	593	4.15	.03	.43	4.78
9	12	74	553	4.87	.03	.32	3.91
10	10	98	537	5.63	.02	.37	3.34
11	12	224	91	0.00	R	R	R
12	6	99	519	6.44	.01	.47	4.08
13	6	74	557	5.63	.02	.38	4.64
14	4	75	549	4.79	.01	.42	5.08
15	8	25	507	4.04	.03	.17	5.44
16	6	89	456	3.18	.02	.70	5.83
17	4	90	330	2.37	.02	.94	5.65
18	4	115	240	1.62	.03	1.64	5.61
19	4	143	146	.81	.06	4.25	7.11
20	20	237	81	0.00	R	R	R
21	76	306	54	0.00	R	R	R

CYCLE COMPOSITE BSHC = .046 GRAM/BHP HR
BSCO+ = .999 GRAM/BHP HR
BSNO2++= 5.116 GRAM/BHP HR
BSHC + BSNO2++= 5.162 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT'11-2869-01 DATE OF TEST'2-2-72 TEST NO.2
ENGINE 'CAT D6C SERIAL NO.' 1A4818

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	0.0	0.0	.05	7.42	7.47	.006
2	1400	0.0	0.0	.14	15.96	16.10	.009
3	1400	61.3	16.3	.20	16.11	16.31	.013
4	1400	122.5	32.7	.28	16.11	16.39	.017
5	1400	182.1	48.5	.36	16.26	16.62	.022
6	1400	246.8	65.8	.45	16.50	16.95	.027
7	1400	309.9	82.6	.54	16.71	17.25	.032
8	1400	369.4	98.5	.63	17.25	17.88	.037
9	1400	432.4	115.3	.74	18.05	18.79	.041
10	1400	490.2	130.7	.82	18.80	19.62	.044
11	640	0.0	0.0	.05	6.92	6.97	.007
12	1900	360.6	130.5	.85	23.85	24.70	.036
13	1900	316.9	114.6	.78	22.78	23.56	.034
14	1900	273.1	98.8	.69	22.27	22.96	.031
15	1900	229.3	83.0	.60	21.58	22.18	.028
16	1900	182.1	65.9	.50	21.15	21.65	.024
17	1900	136.6	49.4	.43	20.72	21.15	.021
18	1900	91.0	32.9	.36	20.50	20.86	.018
19	1900	47.3	17.1	.29	20.55	20.84	.014
20	1900	0.0	0.0	.21	20.52	20.73	.010
21	640	0.0	0.0	.05	6.93	6.98	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	14	333	36	0.00	R	R	R
2	62	344	53	0.00	R	R	R
3	40	222	125	.72	.53	5.84	5.41
4	36	142	259	1.44	.24	1.87	5.62
5	30	115	390	2.14	.14	1.03	5.76
6	34	63	445	2.90	.12	.43	5.50
7	16	88	534	3.63	.04	.48	4.82
8	14	62	529	4.33	.03	.30	4.15
9	16	98	501	5.07	.03	.42	3.53
10	18	134	520	5.75	.04	.53	3.38
11	36	253	71	0.00	R	R	R
12	26	111	485	5.74	.06	.55	3.97
13	18	125	498	5.04	.05	.67	4.42
14	18	113	484	4.35	.06	.69	4.91
15	18	127	482	3.65	.06	.89	5.57
16	18	128	346	2.90	.08	1.10	4.92
17	14	141	267	2.17	.08	1.59	4.93
18	14	168	200	1.45	.12	2.80	5.48
19	18	222	134	.75	.29	7.10	7.07
20	38	277	71	0.00	R	R	R
21	72	332	36	0.00	R	R	R

CYCLE COMPOSITE BSHC = .110 GRAM/BHP HR
BSCO+ = 1.385 GRAM/BHP HR
BSNO2++= 4.715 GRAM/BHP HR
BSHC + BSNO2++= 4.824 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT'11-2869-01 DATE OF TEST'2-9-72 TEST NO.3
ENGINE 'CAT D6C SERIAL NO.' 1A4818

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	0.0	0.0	.05	7.97	8.02	.007
2	1400	0.0	0.0	.13	16.03	16.16	.008
3	1400	64.8	17.3	.20	16.01	16.21	.012
4	1400	126.0	33.6	.27	16.00	16.27	.017
5	1400	189.1	50.4	.36	16.03	16.39	.022
6	1400	253.8	67.7	.44	16.23	16.67	.027
7	1400	316.9	84.5	.52	16.52	17.04	.032
8	1400	381.6	101.7	.63	17.03	17.66	.037
9	1400	441.2	117.6	.72	17.82	18.54	.041
10	1400	491.9	131.1	.81	18.30	19.11	.044
11	640	0.0	0.0	.05	7.32	7.37	.007
12	1900	378.1	136.8	.92	24.25	25.17	.038
13	1900	330.9	119.7	.81	23.10	23.91	.035
14	1900	281.9	102.0	.71	22.22	22.93	.032
15	1900	234.6	84.9	.62	21.62	22.24	.029
16	1900	187.3	67.8	.52	21.33	21.86	.025
17	1900	143.6	51.9	.44	21.00	21.44	.021
18	1900	94.5	34.2	.36	20.62	20.98	.017
19	1900	45.5	16.5	.28	20.65	20.93	.014
20	1900	0.0	0.0	.22	20.93	21.15	.011
21	640	0.0	0.0	.05	7.12	7.17	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	76	332	17	0.00	R	R	R
2	66	318	34	0.00	R	R	R
3	48	315	112	.76	.59	7.78	4.55
4	42	91	259	1.48	.27	1.16	5.43
5	44	76	429	2.22	.19	.65	6.02
6	44	63	566	2.98	.14	.41	6.03
7	44	75	605	3.72	.12	.40	5.28
8	44	62	588	4.48	.10	.28	4.41
9	42	98	561	5.17	.09	.41	3.82
10	40	159	568	5.77	.08	.61	3.57
11	80	253	34	0.00	R	R	R
12	22	62	575	6.02	.05	.30	4.57
13	20	49	590	5.27	.05	.26	5.09
14	18	25	583	4.49	.05	.15	5.66
15	18	25	519	3.73	.06	.18	5.88
16	20	38	427	2.98	.09	.32	5.94
17	24	26	326	2.29	.13	.28	5.81
18	24	51	212	1.50	.19	.83	5.62
19	28	117	130	.72	.47	3.90	7.12
20	62	197	68	0.00	R	R	R
21	108	279	34	0.00	R	R	R

CYCLE COMPOSITE BSHC = .165 GRAM/BHP HR
BSCO+ = .953 GRAM/BHP HR
BSNO2++= 5.123 GRAM/BHP HR
BSHC + BSNO2++= 5.289 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT'11-2869-01 DATE OF TEST'2-9-72 TEST NO.4
ENGINE 'CAT D6C SERIAL NO.' 1A4818

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	0.0	0.0	.05	8.02	8.07	.006
2	1400	0.0	0.0	.13	15.92	16.05	.008
3	1400	61.3	16.3	.19	15.93	16.12	.012
4	1400	122.5	32.7	.27	15.92	16.19	.017
5	1400	183.8	49.0	.33	15.90	16.23	.021
6	1400	248.6	66.3	.42	16.17	16.59	.026
7	1400	309.9	82.6	.51	16.45	16.96	.031
8	1400	369.4	98.5	.61	17.02	17.63	.036
9	1400	432.4	115.3	.71	17.90	18.61	.040
10	1400	490.2	130.7	.82	18.82	19.64	.044
11	640	0.0	0.0	.05	7.45	7.50	.007
12	1900	379.9	137.4	.93	24.52	25.45	.038
13	1900	332.6	120.3	.82	23.20	24.02	.035
14	1900	288.9	104.5	.71	22.30	23.01	.032
15	1900	238.1	86.1	.60	21.88	22.48	.028
16	1900	189.1	68.4	.52	21.42	21.94	.024
17	1900	141.8	51.3	.43	20.98	21.41	.021
18	1900	94.5	34.2	.36	20.82	21.18	.017
19	1900	47.3	17.1	.28	20.82	21.10	.014
20	1900	0.0	0.0	.22	21.07	21.29	.010
21	640	0.0	0.0	.05	7.35	7.40	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	92	306	35	0.00	R	R	R
2	60	252	52	0.00	R	R	R
3	58	131	140	.72	.76	3.39	5.97
4	32	51	260	1.44	.21	.67	5.56
5	32	26	440	2.16	.14	.23	6.30
6	32	26	555	2.92	.11	.17	6.01
7	36	12	606	3.63	.10	.07	5.38
8	34	25	600	4.33	.08	.12	4.64
9	34	37	573	5.07	.07	.16	4.00
10	32	61	557	5.75	.06	.24	3.62
11	92	145	52	0.00	R	R	R
12	32	111	564	6.05	.08	.54	4.51
13	32	112	579	5.29	.08	.59	4.99
14	34	112	549	4.60	.10	.65	5.22
15	36	127	487	3.79	.12	.87	5.50
16	38	140	385	3.01	.16	1.18	5.33
17	38	141	316	2.26	.21	1.55	5.71
18	36	168	175	1.50	.29	2.74	4.68
19	42	196	103	.75	.68	6.35	5.48
20	60	277	59	0.00	R	R	R
21	96	306	52	0.00	R	R	R

CYCLE COMPOSITE BSHC = .185 GRAM/BHP HR
BSCO+ = 1.082 GRAM/BHP HR
BSNO2++= 5.064 GRAM/BHP HR
BSHC + BSNO2++= 5.249 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
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PROJECT'11-2869-01 DATE OF TEST'2-10-72 TEST NO.5
ENGINE 'CAT D6C SERIAL NO.' 1A4818

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	0.0	0.0	.05	7.78	7.83	.006
2	1400	0.0	0.0	.12	15.97	16.09	.008
3	1400	59.5	15.9	.19	15.98	16.17	.012
4	1400	119.0	31.7	.26	15.98	16.24	.016
5	1400	178.6	47.6	.33	15.95	16.28	.021
6	1400	238.1	63.5	.41	16.25	16.66	.025
7	1400	299.4	74.8	.50	16.52	17.02	.030
8	1400	355.4	44.7	.57	17.05	17.62	.033
9	1400	416.7	111.1	.69	17.58	18.27	.039
10	1400	488.4	130.2	.83	18.60	19.43	.045
11	640	0.0	0.0	.05	7.18	7.23	.007
12	1900	420.2	157.0	1.00	25.08	26.08	.040
13	1900	364.1	131.7	.86	23.47	24.33	.037
14	1900	315.1	114.0	.76	22.30	23.06	.034
15	1900	262.6	95.0	.65	21.42	22.07	.030
16	1900	210.1	76.0	.55	20.98	21.53	.026
17	1900	157.6	57.0	.45	20.58	21.03	.022
18	1900	103.3	37.4	.36	20.50	20.86	.018
19	1900	50.8	18.4	.27	20.40	20.67	.013
20	1900	0.0	0.0	.21	20.70	20.91	.010
21	640	0.0	0.0	.05	7.25	7.30	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	72	279	44	0.00	R	R	R
2	64	279	61	0.00	R	R	R
3	66	170	152	.70	.89	4.55	6.7[illegible]
4	58	91	266	1.40	.39	1.22	5.28
5	38	64	397	2.09	.17	.58	5.66
6	36	64	570	2.79	.12	.44	5.47
7	36	75	610	3.51	.10	.42	5.62
8	32	88	617	4.17	.08	.43	4.96
9	30	74	576	4.89	.07	.32	4.09
10	28	109	524	5.73	.06	.43	3.38
11	82	225	61	0.00	R	R	R
12	26	110	575	6.69	.06	.50	4.26
13	24	99	602	5.80	.06	.48	4.80
14	26	112	571	5.02	.07	.59	4.99
15	30	126	553	4.18	.09	.77	5.55
16	34	139	457	3.34	.13	1.04	5.59
17	34	141	344	2.51	.17	1.36	5.48
18	36	168	256	1.64	.27	2.46	6.18
19	40	222	161	.81	.59	6.57	7.84
20	76	330	106	0.00	R	R	R
21	114	359	61	0.00	R	R	R

CYCLE COMPOSITE BSHC = .175 GRAM/BHP HR
BSCO+ = 1.225 GRAM/BHP HR
BSNO2++= 5.178 GRAM/BHP HR
BSHC + BSNO2++= 5.353 GRAM/BHP HR

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PROJECT'11-2869-01 DATE OF TEST'2-10-72 TEST NO.6
ENGINE 'CAT D6C SERIAL NO.' 1A4818

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	0.0	0.0	.05	7.92	7.97	.006
2	1400	0.0	0.0	.12	15.95	16.07	.008
3	1400	61.3	16.3	.19	15.95	16.14	.012
4	1400	122.5	32.7	.27	15.93	16.20	.017
5	1400	185.6	49.5	.35	16.2[illegible]	16.60	.022
6	1400	245.1	65.3	.41	16.53	16.94	.025
7	1400	306.4	81.7	.52	16.48	17.50	.030
8	1400	364.4	98.5	.64	17.32	17.96	.037
9	1400	434.2	115.7	.73	18.08	18.81	.041
10	1400	490.2	130.7	.84	19.08	19.92	.044
11	640	0.0	0.0	.05	7.35	7.40	.007
12	1900	413.2	149.5	.99	25.42	26.41	.039
13	1900	367.6	133.0	.87	23.90	24.77	.037
14	1900	313.4	113.4	.76	22.78	23.54	.033
15	1900	264.4	95.6	.65	21.70	22.35	.030
16	1900	208.3	75.4	.54	21.13	21.67	.026
17	1900	157.6	57.0	.46	20.87	21.33	.022
18	1900	105.0	38.0	.37	20.72	21.09	.018
19	1900	52.5	19.0	.28	20.73	21.01	.014
20	1900	1.8	.6	.21	20.98	21.19	.010
21	640	0.0	0.0	.05	7.78	7.83	.006

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	84	360	36	0.00	R	R	R
2	70	318	62	0.00	R	R	R
3	36	223	145	.72	.47	5.78	6.21
4	30	91	290	1.44	.20	1.18	6.20
5	28	64	457	2.18	.12	.57	6.62
6	26	76	614	2.87	.09	.52	6.88
7	24	75	654	3.59	.07	.42	6.06
8	22	62	634	4.33	.05	.30	5.00
9	20	86	594	5.09	.04	.37	4.17
10	14	98	601	5.75	.03	.39	3.96
11	84	279	54	0.00	R	R	R
12	24	111	550	6.58	.06	.51	4.20
13	24	111	564	5.85	.06	.54	4.54
14	30	75	592	4.99	.08	.41	5.31
15	30	113	537	4.21	.09	.69	5.43
16	36	114	453	3.32	.14	.86	5.62
17	34	115	370	2.51	.17	1.13	5.98
18	36	129	229	1.67	.26	1.89	5.50
19	40	169	125	.84	.58	4.92	5.99
20	64	264	99	.03	28.26	231.99	143.35
21	106	319	44	0.00	R	R	R

CYCLE COMPOSITE BSHC = .154 GRAM/BHP HR
BSCO+ = 1.170 GRAM/BHP HR
BSNO2++= 5.275 GRAM/BHP HR
BSHC + BSNO2++= 5.429 GRAM/BHP HR

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PROJECT' 11-2869-01 DATE OF TEST' 10-24-72 TEST NO.3
ENGINE' GM 6V-71N SERIAL NO.' 00000

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	440	5.3	.4	.04	9.25	9.29	.005
2	1600	3.5	1.1	.20	36.88	37.08	.005
3	1600	75.3	22.9	.30	36.88	37.18	.008
4	1600	140.1	42.7	.39	36.88	37.27	.011
5	1600	210.1	64.0	.47	36.32	36.79	.013
6	1600	283.6	86.4	.63	36.25	36.88	.017
7	1600	355.4	108.3	.73	36.77	37.50	.020
8	1600	421.9	128.5	.88	37.66	38.54	.023
9	1600	491.9	149.9	1.03	36.22	37.25	.029
10	1600	553.2	168.5	1.17	36.22	37.39	.032
11	440	3.5	.3	.04	8.76	8.80	.005
12	2100	514.7	205.8	1.45	47.91	49.36	.030
13	2100	455.2	182.0	1.27	47.82	49.09	.027
14	2100	386.9	154.7	1.17	46.42	47.59	.025
15	2100	322.1	128.8	.88	48.99	49.87	.018
16	2100	253.8	101.5	.73	45.77	46.50	.016
17	2100	192.6	77.0	.65	46.14	46.79	.014
18	2100	131.3	52.5	.53	46.75	47.28	.011
19	2100	61.3	24.5	.38	49.03	49.41	.008
20	2100	7.0	2.8	.28	49.08	49.36	.006
21	440	3.5	.3	.05	9.59	9.64	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	96	226	184	.03	26.76	125.49	167.96
2	96	162	164	.05	44.05	148.31	246.40
3	98	87	324	1.01	2.10	3.69	22.66
4	100	49	507	1.88	1.15	1.12	19.15
5	104	37	736	2.82	.79	.56	18.27
6	106	24	1032	3.80	.60	.27	19.03
7	116	24	1310	4.76	.53	.22	19.61
8	122	48	1547	5.66	.48	.38	20.04
9	146	399	1662	6.59	.48	2.61	17.85
10	158	2143	1536	7.42	.46	12.51	14.72
11	112	162	284	.02	44.36	128.19	367.53
12	146	459	1695	9.06	.46	2.90	17.57
13	138	95	1709	8.01	.49	.67	19.91
14	132	36	1579	6.81	.54	.29	20.98
15	126	48	1298	5.67	.64	.49	21.72
16	124	48	1081	4.47	.75	.58	21.39
17	124	49	854	3.39	.99	.78	22.42
18	122	62	662	2.31	1.45	1.46	25.77
19	126	74	453	1.08	3.35	3.92	39.51
20	132	99	283	.12	30.72	45.83	215.50
21	112	187	253	.02	48.59	161.65	359.55

CYCLE COMPOSITE BSHC = .776 GRAM/BHP HR
BSCO+ = 2.572 GRAM/BHP HR
BSNO2++= 20.435 GRAM/BHP HR
BSHC + BSNO2++= 21.211 GRAM/BHP HR

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PROJECT' 11-2869-01 DATE OF TEST' 10-24-72 TEST NO.4
ENGINE' GM 6V-71N SERIAL NO.' 00000

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	440	5.3	.4	.04	9.34	9.38	.004
2	1600	3.5	1.1	.17	36.23	36.40	.005
3	1600	71.8	21.9	.27	36.57	36.84	.007
4	1600	140.1	42.7	.38	36.20	36.58	.011
5	1600	213.6	65.1	.50	36.30	36.80	.014
6	1600	281.9	85.9	.62	35.89	36.51	.017
7	1600	355.4	108.3	.73	35.96	36.69	.020
8	1600	425.4	129.6	.87	35.96	36.83	.024
9	1600	491.9	149.9	1.02	35.83	36.85	.029
10	1600	560.2	170.7	1.20	36.27	37.47	.033
11	440	3.5	.3	.04	9.22	9.26	.005
12	2100	521.7	208.6	1.46	47.84	49.30	.030
13	2100	456.9	182.7	1.30	47.75	49.05	.027
14	2100	386.9	154.7	1.10	46.26	47.36	.024
15	2100	323.9	129.5	.93	46.26	47.19	.020
16	2100	262.6	105.0	.89	49.05	49.94	.018
17	2100	192.6	77.0	.66	46.50	47.16	.014
18	2100	127.8	51.1	.52	47.89	48.41	.011
19	2100	63.0	25.2	.43	49.01	49.44	.009
20	2100	7.0	2.8	.32	48.96	49.28	.006
21	440	3.5	.3	.05	9.60	9.65	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	88	213	252	.03	24.77	119.49	232.53
2	94	174	203	.05	42.35	156.45	298.92
3	84	111	364	.96	1.87	4.93	26.52
4	84	73	551	1.88	.95	1.66	20.42
5	88	49	744	2.86	.66	.72	18.18
6	94	48	984	3.78	.53	.54	18.07
7	100	48	1221	4.76	.45	.43	17.87
8	116	84	1465	5.70	.44	.63	17.98
9	138	473	1616	6.59	.45	3.06	17.17
10	132	2469	1491	7.51	.38	14.26	14.14
11	108	226	262	.02	45.01	187.62	357.04
12	142	623	1629	9.18	.44	3.87	16.63
13	132	155	1640	8.04	.47	1.09	19.03
14	130	59	1466	6.81	.53	.48	19.39
15	130	48	1270	5.70	.63	.46	20.00
16	130	60	1055	4.62	.82	.75	21.69
17	128	60	822	3.39	1.03	.97	21.76
18	128	61	635	2.25	1.60	1.51	25.98
19	134	74	462	1.11	3.47	3.80	39.12
20	138	99	291	.12	32.06	45.69	221.59
21	116	187	252	.02	50.37	161.82	358.23

CYCLE COMPOSITE BSHC = .745 GRAM/BHP HR
BSCO+ = 3.087 GRAM/BHP HR
BSNO2++= 19.645 GRAM/BHP HR
BSHC + BSNO2++= 20.389 GRAM/BHP HR

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PROJECT' 11-2869-01 DATE OF TEST' 10-25-72 TEST NO.5
ENGINE' GM 6V-71N SERIAL NO.' 00000

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	440	3.5	.3	.04	9.12	9.16	.004
2	1600	3.5	1.1	.19	36.88	37.07	.005
3	1600	73.5	22.4	.30	37.14	37.44	.008
4	1600	141.8	43.2	.40	36.58	36.98	.011
5	1600	210.1	64.0	.52	37.51	38.03	.014
6	1600	283.6	86.4	.64	36.29	36.93	.018
7	1600	355.4	108.3	.75	35.79	36.54	.021
8	1600	421.9	128.5	.86	35.89	36.75	.024
9	1600	495.4	150.9	1.05	35.94	36.99	.029
10	1600	558.5	170.1	1.21	36.06	37.27	.034
11	440	3.5	.3	.05	9.01	9.06	.006
12	2100	521.7	208.6	1.47	47.24	48.71	.031
13	2100	456.9	182.7	1.31	47.18	48.49	.028
14	2100	388.6	155.4	1.11	48.99	50.10	.023
15	2100	327.4	130.9	.95	45.73	46.68	.021
16	2100	259.1	103.6	.79	45.57	46.36	.017
17	2100	192.6	77.0	.65	46.58	47.23	.014
18	2100	127.8	51.1	.54	46.28	46.82	.012
19	2100	63.0	25.2	.40	48.00	48.40	.008
20	2100	7.0	2.8	.31	48.73	49.04	.006
21	440	3.5	.3	.06	9.47	9.53	.006

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	76	213	237	.02	31.33	175.03	319.64
2	80	149	207	.05	36.70	136.61	310.81
3	72	98	394	.99	1.59	4.32	28.41
4	74	62	587	1.90	.84	1.39	21.72
5	74	49	800	2.82	.58	.76	20.54
6	78	48	1049	3.80	.44	.54	19.37
7	82	48	1296	4.76	.37	.43	18.89
8	92	84	1535	5.66	.35	.63	18.95
9	108	498	1708	6.64	.35	3.21	18.08
10	104	2531	1577	7.49	.30	14.58	14.92
11	80	238	247	.02	32.63	193.52	329.27
12	108	673	1701	9.18	.33	4.13	17.16
13	98	155	1713	8.04	.34	1.08	19.64
14	98	84	1595	6.84	.42	.71	22.21
15	100	72	1364	5.76	.47	.67	21.02
16	100	72	1080	4.56	.59	.85	20.88
17	102	73	840	3.39	.83	1.18	22.27
18	102	73	648	2.25	1.23	1.77	25.63
19	104	87	449	1.11	2.64	4.37	37.27
20	110	112	287	.12	25.43	51.38	217.41
21	94	225	247	.02	40.30	192.38	345.99

CYCLE COMPOSITE BSHC = .586 GRAM/BHP HR
BSCO+ = 3.223 GRAM/BHP HR
BSNO2++= 20.539 GRAM/BHP HR
BSHC + BSNO2++= 21.126 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
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PROJECT' 11-2869-01   DATE OF TEST' 5-09-72 TEST NO.4
ENGINE' INTERNATIONAL D407 SERIAL NO.' 54725

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.03	4.97	5.00	.006
2	1800	0.0	0.0	.09	12.02	12.11	.008
3	1800	35.0	12.0	.15	12.13	12.28	.013
4	1800	70.0	24.0	.20	12.10	12.31	.017
5	1800	105.0	36.0	.25	11.84	12.09	.022
6	1800	140.1	48.0	.32	11.92	12.24	.027
7	1800	175.1	60.0	.38	11.73	12.11	.032
8	1800	210.1	72.0	.46	11.84	12.30	.039
9	1800	245.1	84.0	.56	11.80	12.36	.047
10	1800	280.1	96.0	.64	11.55	12.19	.055
11	700	0.0	0.0	.02	4.89	4.91	.004
12	2500	238.1	113.3	.78	15.74	16.52	.049
13	2500	210.1	100.0	.68	15.73	16.41	.043
14	2500	180.3	85.8	.57	15.82	16.39	.036
15	2500	150.6	71.7	.51	15.93	16.44	.032
16	2500	119.0	56.7	.42	15.94	16.36	.026
17	2500	89.3	42.5	.35	15.97	16.32	.022
18	2500	61.3	29.2	.28	16.02	16.30	.018
19	2500	29.8	14.2	.22	16.06	16.28	.014
20	2500	0.0	0.0	.17	16.08	16.25	.010
21	700	0.0	0.0	.03	4.69	4.72	.006

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	465	289	165	0.00	R	R	R
2	605	382	90	0.00	R	R	R
3	555	378	183	.53	7.50	10.18	8.08
4	520	328	294	1.06	3.52	4.43	6.50
5	510	325	397	1.58	2.26	2.87	5.77
6	545	374	565	2.11	1.83	2.54	6.23
7	580	490	730	2.64	1.54	2.60	6.36
8	710	1024	933	3.17	1.60	4.60	6.89
9	915	2679	1123	3.70	1.78	10.36	7.14
10	870	7253	1239	4.22	1.46	24.22	6.79
11	545	266	171	0.00	R	R	R
12	1040	2204	1471	4.99	2.00	8.45	9.26
13	860	1142	1319	4.40	1.86	4.93	9.35
14	700	673	1091	3.78	1.76	3.38	9.00
15	705	514	863	3.15	2.13	3.10	8.55
16	730	425	624	2.49	2.78	3.23	7.78
17	700	442	436	1.87	3.55	4.46	7.23
18	700	457	313	1.28	5.16	6.72	7.55
19	730	485	212	.62	11.08	14.66	10.51
20	780	489	119	0.00	R	R	R
21	575	324	180	0.00	R	R	R

CYCLE COMPOSITE BSHC = 2.744 GRAM/BHP HR
BSCO+ = 7.804 GRAM/BHP HR
BSNO2++= 8.115 GRAM/BHP HR
BSHC + BSNO2++= 10.859 GRAM/BHP HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 5-9-72 TEST NO.5
ENGINE' INTERNATIONAL D407 SERIAL NO.' 54725

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.02	5.13	5.15	.005
2	1800	0.0	0.0	.09	12.16	12.25	.008
3	1800	33.3	11.4	.14	12.06	12.20	.012
4	1800	70.0	24.0	.20	12.01	12.21	.016
5	1800	105.0	36.0	.26	12.04	12.30	.022
6	1800	140.1	48.0	.33	11.99	12.32	.027
7	1800	175.1	60.0	.39	12.06	12.45	.033
8	1800	210.1	72.0	.46	11.79	12.25	.039
9	1800	245.1	84.0	.56	11.88	12.44	.048
10	1800	280.1	96.0	.64	11.40	12.04	.056
11	700	0.0	0.0	.02	4.89	4.91	.004
12	2500	225.8	107.5	.73	15.81	16.54	.046
13	2500	197.8	94.2	.64	15.98	16.62	.040
14	2500	169.8	80.8	.55	15.76	16.31	.035
15	2500	140.1	66.7	.48	16.12	16.60	.030
16	2500	112.0	53.3	.41	16.10	16.51	.026
17	2500	84.0	40.0	.34	16.16	16.50	.021
18	2500	56.0	26.7	.29	16.18	16.47	.018
19	2500	28.0	13.3	.22	16.26	16.48	.014
20	2500	0.0	0.0	.16	16.16	16.32	.010
21	700	0.0	0.0	.02	5.25	5.27	.004

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	415	254	166	0.00	R	R	R
2	575	335	95	0.00	R	R	R
3	545	320	163	.50	7.70	9.01	7.54
4	570	294	289	1.06	3.83	3.93	6.35
5	550	302	407	1.58	2.48	2.72	6.00
6	560	333	536	2.11	1.90	2.25	5.94
7	610	443	767	2.64	1.67	2.42	6.87
8	760	986	910	3.17	1.71	4.41	6.69
9	980	2869	1123	3.70	1.92	11.18	7.18
10	800	7232	1157	4.22	1.32	23.86	6.27
11	540	266	196	0.00	R	R	R
12	1050	1864	1448	4.73	2.13	7.54	9.62
13	830	910	1281	4.14	1.93	4.22	9.77
14	720	557	1047	3.56	1.92	2.96	9.13
15	760	434	809	2.93	2.50	2.84	8.70
16	765	392	615	2.35	3.13	3.19	8.22
17	750	383	437	1.76	4.08	4.16	7.78
18	725	398	312	1.17	5.91	6.47	8.34
19	740	413	217	.59	12.07	13.44	11.57
20	785	416	159	0.00	R	R	R
21	600	289	176	0.00	R	R	R

CYCLE COMPOSITE BSHC = 2.927 GRAM/BHP HR
BSCO+ = 7.520 GRAM/BHP HR
BSNO2++= 8.295 GRAM/BHP HR
BSHC + BSNO2++= 11.222 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 5-10-72 TEST NO.6
ENGINE' INTERNATIONAL D407 SERIAL NO.' 54725

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.03	4.96	4.99	.005
2	1800	0.0	0.0	.09	12.17	12.26	.007
3	1800	35.0	12.0	.15	12.33	12.48	.012
4	1800	70.0	24.0	.21	12.16	12.37	.017
5	1800	105.0	36.0	.26	12.42	12.69	.021
6	1800	140.1	48.0	.32	11.87	12.19	.027
7	1800	175.1	60.0	.38	11.79	12.17	.032
8	1800	210.1	72.0	.48	12.07	12.55	.040
9	1800	245.1	84.0	.58	12.02	12.60	.048
10	1800	280.1	96.0	.66	11.66	12.32	.056
11	700	0.0	0.0	.03	5.05	5.08	.005
12	2500	229.3	109.2	.73	15.82	16.55	.046
13	2500	203.1	96.7	.65	15.86	16.51	.041
14	2500	173.3	82.5	.57	15.93	16.50	.036
15	2500	143.6	68.3	.49	16.02	16.51	.031
16	2500	115.5	55.0	.42	16.18	16.60	.026
17	2500	87.5	41.7	.35	16.26	16.61	.022
18	2500	57.8	27.5	.28	16.26	16.54	.018
19	2500	28.0	13.3	.23	16.08	16.31	.014
20	2500	0.0	0.0	.17	16.32	16.49	.010
21	700	0.0	0.0	.02	4.86	4.88	.004

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	464	277	188	0.00	R	R	R
2	691	347	91	0.00	R	R	R
3	513	344	151	.53	7.04	9.39	6.76
4	592	317	268	1.06	4.03	4.29	5.97
5	553	314	364	1.58	2.57	2.91	5.54
6	612	344	520	2.11	2.05	2.30	5.71
7	533	432	712	2.64	1.43	2.31	6.24
8	671	862	899	3.17	1.54	3.95	6.77
9	829	2136	1058	3.70	1.64	8.43	6.85
10	730	6721	1186	4.22	1.24	22.68	6.57
11	592	265	163	0.00	R	R	R
12	888	1792	1481	4.80	1.78	7.15	9.70
13	711	908	1334	4.25	1.60	4.08	9.84
14	701	544	1074	3.63	1.85	2.86	9.28
15	651	421	834	3.01	2.08	2.68	8.71
16	701	356	614	2.42	2.79	2.83	8.01
17	642	360	413	1.83	3.38	3.77	7.12
18	711	386	322	1.21	5.65	6.11	8.38
19	661	389	210	.59	10.67	12.50	11.09
20	553	368	161	0.00	R	R	R
21	385	254	153	0.00	R	R	R

CYCLE COMPOSITE BSHC = 2.632 GRAM/BHP HR
BSCO+ = 6.922 GRAM/BHP HR
BSNO2++= 8.186 GRAM/BHP HR
BSHC + BSNO2++= 10.818 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 5-11-72 TEST NO.7
ENGINE' INTERNATIONAL D407 SERIAL NO.' 54725

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.03	5.07	5.10	.005
2	1800	0.0	0.0	.09	12.33	12.42	.008
3	1800	35.0	12.0	.14	11.86	12.00	.012
4	1800	70.0	24.0	.20	12.18	12.38	.017
5	1800	105.0	36.0	.26	12.27	12.53	.021
6	1800	140.1	48.0	.32	12.10	12.42	.026
7	1800	175.1	60.0	.39	12.15	12.54	.032
8	1800	210.1	72.0	.46	11.88	12.34	.039
9	1800	245.1	84.0	.54	12.10	12.64	.045
10	1800	281.9	96.6	.65	11.87	12.52	.055
11	700	0.0	0.0	.02	4.86	4.88	.004
12	2500	227.6	108.3	.72	15.84	16.56	.046
13	2500	201.3	95.8	.67	15.98	16.65	.042
14	2500	173.3	82.5	.56	15.93	16.49	.035
15	2500	141.8	67.5	.49	16.09	16.58	.030
16	2500	113.8	54.2	.41	16.09	16.50	.026
17	2500	84.0	40.0	.34	16.28	16.62	.021
18	2500	57.8	27.5	.30	16.10	16.40	.019
19	2500	26.3	12.5	.20	16.07	16.27	.013
20	2500	0.0	0.0	.18	16.19	16.37	.011
21	700	0.0	0.0	.03	4.67	4.70	.006

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	553	277	161	0.00	R	R	R
2	829	358	90	0.00	R	R	R
3	691	367	179	.53	9.13	9.65	7.72
4	750	317	275	1.06	5.11	4.30	6.14
5	632	430	395	1.58	2.90	3.93	5.93
6	750	345	545	2.11	2.56	2.35	6.09
7	691	478	781	2.64	1.91	2.63	7.05
8	849	938	939	3.17	1.92	4.23	6.95
9	869	2181	1158	3.70	1.73	8.63	7.53
10	592	7106	1268	4.25	1.01	24.23	7.10
11	434	254	162	0.00	R	R	R
12	730	1739	1422	4.77	1.47	6.99	9.40
13	582	858	1259	4.22	1.33	3.92	9.45
14	533	534	1017	3.63	1.41	2.80	8.78
15	513	411	765	2.97	1.66	2.65	8.12
16	553	357	570	2.38	2.22	2.86	7.50
17	474	360	409	1.76	2.60	3.94	7.35
18	543	362	284	1.21	4.27	5.68	7.32
19	454	390	159	.55	7.80	13.35	8.93
20	572	391	129	0.00	R	R	R
21	434	288	151	0.00	R	R	R

CYCLE COMPOSITE BSHC = 2.509 GRAM/BHP HR
BSCO+ = 7.195 GRAM/BHP HR
BSNO2++= 8.133 GRAM/BHP HR
BSHC + BSNO2++= 10.641 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT'11-2869-01 DATE OF TEST'3-3-72 TEST NO.1
ENGINE 'JOHN DEERE 6404 SERIAL NO.'TR03-311102

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	0.0	0.0	.05	6.30	6.35	.008
2	1500	0.0	0.0	.13	10.74	10.87	.012
3	1500	45.5	13.0	.18	11.19	11.37	.016
4	1500	92.8	26.5	.25	11.96	12.21	.021
5	1500	136.6	39.0	.31	12.45	12.76	.025
6	1500	183.8	52.5	.38	13.07	13.45	.029
7	1500	227.6	65.0	.44	13.22	13.66	.033
8	1500	274.9	78.5	.49	14.03	14.52	.035
9	1500	320.4	91.5	.61	14.65	15.26	.042
10	1500	357.1	102.0	.66	14.45	15.11	.046
11	800	0.0	0.0	.05	6.30	6.35	.007
12	2200	323.9	135.7	.93	24.21	25.14	.039
13	2200	287.1	120.3	.86	23.59	24.45	.036
14	2200	246.8	103.4	.74	22.51	23.25	.033
15	2200	206.6	86.5	.66	21.84	22.50	.030
16	2200	162.8	68.2	.55	19.79	20.34	.028
17	2200	124.3	52.1	.46	19.02	19.48	.024
18	2200	80.5	33.7	.38	18.00	18.38	.021
19	2200	42.0	17.6	.30	17.21	17.51	.017
20	2200	0.0	0.0	.20	15.89	16.09	.013
21	800	0.0	0.0	.04	5.98	6.02	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	1256	699	42	0.00	R	R	R
2	3200	1320	8	0.00	R	R	R
3	2400	1072	41	.57	27.70	24.65	1.57
4	1488	640	162	1.17	9.05	7.76	3.23
5	1312	451	253	1.72	5.66	3.88	3.57
6	1296	459	347	2.31	4.38	3.10	3.84
7	1280	494	445	2.86	3.55	2.73	4.04
8	1072	673	550	3.45	2.62	3.28	4.40
9	736	1348	654	4.03	1.62	5.91	4.71
10	592	2245	671	4.49	1.16	8.75	4.30
11	528	590	112	0.00	R	R	R
12	656	488	1061	5.97	1.60	2.38	8.50
13	640	414	796	5.29	1.72	2.22	6.99
14	656	239	597	4.55	1.95	1.41	5.80
15	688	138	490	3.81	2.36	.94	5.50
16	640	152	337	3.00	2.52	1.19	4.35
17	592	166	271	2.29	2.92	1.63	4.39
18	704	258	198	1.48	5.06	3.69	4.66
19	768	351	145	.77	10.08	9.19	6.24
20	992	543	59	0.00	R	R	R
21	1008	453	51	0.00	R	R	R

CYCLE COMPOSITE BSHC = 3.939 GRAM/BHP HR
BSCO+ = 4.626 GRAM/BHP HR
BSNO2++= 5.449 GRAM/BHP HR
BSHC + BSNO2++= 9.387 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT'11-2869-01 DATE OF TEST'3-6-72 TEST NO.2
ENGINE 'JOHN DEERE 6404 SERIAL NO.'TR03-311102

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	0.0	0.0	.04	6.17	6.21	.007
2	1500	0.0	0.0	.12	11.05	11.17	.011
3	1500	45.5	13.0	.17	11.14	11.31	.015
4	1500	91.0	26.0	.23	11.23	11.46	.021
5	1500	136.6	39.0	.30	12.17	12.47	.025
6	1500	183.8	52.5	.37	12.50	12.87	.029
7	1500	227.6	65.0	.44	12.97	13.41	.034
8	1500	273.1	78.0	.51	13.57	14.08	.037
9	1500	318.6	91.0	.60	14.50	15.10	.041
10	1500	362.4	103.5	.68	15.37	16.05	.044
11	800	0.0	0.0	.04	5.83	5.87	.007
12	2200	322.1	134.9	.94	24.10	25.04	.039
13	2200	288.9	121.0	.85	22.82	23.67	.037
14	2200	248.6	104.1	.75	21.92	22.67	.034
15	2200	206.6	86.5	.65	20.99	21.64	.031
16	2200	166.3	69.7	.58	20.51	21.09	.028
17	2200	122.5	51.3	.47	18.93	19.40	.025
18	2200	82.3	34.5	.37	17.50	17.87	.021
19	2200	66.5	27.9	.34	17.27	17.61	.020
20	2200	0.0	0.0	.21	16.26	16.47	.013
21	800	0.0	0.0	.04	5.66	5.70	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	1184	306	90	0.00	R	R	R
2	1776	956	36	0.00	R	R	R
3	1456	783	71	.57	16.72	17.92	2.66
4	1168	481	161	1.14	6.80	5.58	3.06
5	1088	307	256	1.72	4.59	2.58	3.54
6	1088	304	354	2.31	3.52	1.96	3.75
7	1120	366	456	2.86	3.05	1.98	4.07
8	1168	489	564	3.43	2.78	2.32	4.40
9	1136	1094	677	4.00	2.49	4.78	4.86
10	960	2012	824	4.55	1.97	8.20	5.52
11	864	359	109	0.00	R	R	R
12	800	476	1225	5.94	1.96	2.32	9.82
13	816	325	917	5.32	2.11	1.67	7.75
14	784	162	652	4.58	2.25	.93	6.13
15	736	100	504	3.81	2.43	.66	5.44
16	704	89	429	3.07	2.81	.71	5.61
17	640	140	306	2.26	3.19	1.39	5.00
18	640	454	219	1.52	4.38	6.19	4.90
19	656	482	161	1.23	5.47	8.01	4.40
20	816	570	80	0.00	R	R	R
21	784	453	62	0.00	R	R	R

CYCLE COMPOSITE BSHC = 3.652 GRAM/BHP HR
BSCO+ = 3.820 GRAM/BHP HR
BSNO2++= 5.972 GRAM/BHP HR
BSHC + BSNO2++= 9.624 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT'11-2869-01 DATE OF TEST'3-6-72 TEST NO.3
ENGINE 'JOHN DEERE 6404 SERIAL NO.'TR03-311102

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	0.0	0.0	.04	5.99	6.03	.007
2	1500	0.0	0.0	.13	10.66	10.79	.012
3	1500	43.8	12.5	.17	10.76	10.93	.015
4	1500	91.0	26.0	.23	11.47	11.70	.020
5	1500	138.3	39.5	.30	12.23	12.53	.024
6	1500	185.6	53.0	.39	13.10	13.49	.030
7	1500	229.3	65.5	.44	13.25	13.69	.033
8	1500	271.4	77.5	.51	13.62	14.13	.037
9	1500	318.6	91.0	.60	14.40	15.00	.042
10	1500	358.9	102.5	.69	14.68	15.37	.047
11	800	0.0	0.0	.04	5.99	6.03	.007
12	2200	322.1	134.9	.94	24.26	25.20	.039
13	2200	288.9	121.0	.85	23.21	24.06	.037
14	2200	246.8	103.4	.74	22.11	22.85	.034
15	2200	208.3	87.3	.66	21.42	22.08	.031
16	2200	164.6	68.9	.55	19.57	20.12	.028
17	2200	124.3	52.1	.49	18.58	19.07	.026
18	2200	82.3	34.5	.37	17.70	18.07	.021
19	2200	42.0	17.6	.30	16.95	17.25	.018
20	2200	0.0	0.0	.20	15.60	15.80	.013
21	800	0.0	0.0	.04	5.82	5.86	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	768	495	56	0.00	R	R	R
2	1408	1136	9	0.00	R	R	R
3	1136	989	36	.55	13.11	22.75	1.37
4	960	614	137	1.14	5.70	7.27	2.67
5	928	438	224	1.74	3.88	3.65	3.06
6	976	394	312	2.33	3.28	2.64	3.43
7	1072	494	415	2.88	2.96	2.71	3.75
8	1152	592	512	3.41	2.77	2.84	4.03
9	1200	1240	635	4.00	2.61	5.38	4.52
10	1056	2225	816	4.51	2.09	8.78	5.29
11	912	399	84	0.00	R	R	R
12	896	553	1119	5.94	2.21	2.71	9.03
13	880	452	848	5.32	2.31	2.37	7.29
14	848	340	634	4.55	2.47	1.97	6.05
15	816	265	507	3.84	2.73	1.77	5.54
16	752	267	377	3.03	2.90	2.05	4.75
17	688	294	293	2.29	3.33	2.83	4.63
18	704	375	205	1.52	4.87	5.18	4.65
19	752	484	148	.77	9.73	12.48	6.25
20	880	624	73	0.00	R	R	R
21	784	521	64	0.00	R	R	R

CYCLE COMPOSITE BSHC = 3.645 GRAM/BHP HR
BSCO+ = 4.747 GRAM/BHP HR
BSNO2++= 5.595 GRAM/BHP HR
BSHC + BSNO2++= 9.241 GRAM/BHP HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT'11-2869-01 DATE OF TEST'3-6-72 TEST NO.4
ENGINE 'JOHN DEERE 6404 SERIAL NO.'TR03-311102

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	800	0.0	0.0	.04	5.98	6.02	.007
2	1500	0.0	0.0	.12	10.74	10.86	.011
3	1500	43.8	12.5	.17	11.02	11.19	.015
4	1500	91.0	26.0	.24	11.72	11.96	.020
5	1500	136.6	39.0	.30	11.97	12.27	.025
6	1500	183.8	52.5	.37	12.46	12.83	.030
7	1500	229.3	65.5	.46	13.67	14.13	.034
8	1500	273.1	78.0	.52	13.89	14.41	.037
9	1500	318.6	91.0	.61	14.79	15.40	.041
10	1500	358.9	102.5	.66	14.31	14.97	.046
11	800	0.0	0.0	.04	6.15	6.19	.007
12	2200	325.6	136.4	.94	24.43	25.37	.038
13	2200	285.4	119.5	.84	23.18	24.02	.036
14	2200	248.6	104.1	.76	22.08	22.84	.034
15	2200	206.6	86.5	.67	21.62	22.29	.031
16	2200	164.6	68.9	.56	19.70	20.26	.028
17	2200	122.5	51.3	.46	18.55	19.01	.025
18	2200	82.3	34.5	.37	17.62	17.99	.021
19	2200	42.0	17.6	.29	16.93	17.22	.017
20	2200	0.0	0.0	.21	16.20	16.41	.013
21	800	0.0	0.0	.04	6.15	6.19	.006

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	768	535	86	0.00	R	R	R
2	1392	1180	28	0.00	R	R	R
3	1152	1003	65	.55	13.61	23.62	2.50
4	976	695	151	1.14	5.92	8.40	2.99
5	896	490	249	1.72	3.72	4.06	3.39
6	944	497	351	2.31	3.05	3.20	3.71
7	1008	520	448	2.88	2.87	2.95	4.17
8	1040	592	559	3.43	2.54	2.88	4.46
9	1056	1281	689	4.00	2.36	5.70	5.04
10	1008	2371	865	4.51	1.94	9.11	5.46
11	944	481	86	0.00	R	R	R
12	1024	604	1228	6.00	2.51	2.95	9.87
13	944	465	913	5.26	2.50	2.46	7.92
14	928	339	700	4.58	2.69	1.96	6.63
15	880	265	532	3.81	2.99	1.80	5.92
16	784	254	408	3.03	3.04	1.96	5.18
17	720	295	291	2.26	3.52	2.87	4.65
18	736	375	210	1.52	5.07	5.15	4.75
19	752	471	152	.77	9.71	12.13	6.41
20	864	610	65	0.00	R	R	R
21	768	510	57	0.00	R	R	R

CYCLE COMPOSITE BSHC = 3.719 GRAM/BHP HR
BSCO+ = 4.986 GRAM/BHP HR
BSNO2++= 6.073 GRAM/BHP HR
BSHC + BSNO2++= 9.792 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2369-001 DATE OF TEST' 1-04-73 TEST NO.1
ENGINE' MERCEDES OM636 SERIAL NO.' 636.941-019625

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	680	0.0	0.0	.02	1.55	1.57	.014
2	1400	0.0	0.0	.03	2.92	2.95	.011
3	1400	7.6	2.0	.05	2.93	2.99	.018
4	1400	15.1	4.0	.06	2.91	2.96	.019
5	1400	22.7	6.1	.07	2.90	2.97	.024
6	1400	30.2	8.0	.07	2.85	2.92	.026
7	1400	37.8	10.1	.09	2.87	2.96	.032
8	1400	45.3	12.1	.11	2.84	2.94	.038
9	1400	52.9	14.1	.12	2.79	2.90	.042
10	1400	60.4	16.1	.14	2.71	2.85	.052
11	700	0.0	0.0	.02	1.48	1.50	.012
12	2400	61.7	28.2	.26	4.69	4.95	.055
13	2400	53.6	24.5	.20	4.68	4.89	.044
14	2400	46.3	21.2	.19	4.68	4.87	.041
15	2400	37.9	17.3	.16	4.68	4.84	.035
16	2400	30.9	14.1	.15	4.78	4.93	.031
17	2400	19.8	9.1	.11	4.78	4.90	.024
18	2400	15.5	7.1	.10	4.88	4.99	.022
19	2400	7.1	3.2	.09	4.79	4.87	.018
20	2400	0.0	0.0	.07	4.99	5.06	.014
21	700	0.0	0.0	.02	1.52	1.54	.012

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	138	418	213	0.00	R	R	R
2	138	337	64	0.00	R	R	R
3	147	222	169	.09	2.85	8.58	10.75
4	158	216	199	.18	1.54	4.19	6.33
5	189	266	262	.27	1.22	3.44	5.54
6	209	274	283	.35	1.00	2.62	4.44
7	196	285	281	.44	.76	2.20	3.56
8	176	291	295	.53	.57	1.87	3.11
9	140	303	292	.62	.38	1.64	2.60
10	241	1431	233	.71	.56	6.67	1.79
11	118	348	199	0.00	R	R	R
12	184	2428	292	1.24	.43	11.21	2.21
13	202	446	333	1.08	.53	2.34	2.88
14	256	403	340	.93	.78	2.44	3.38
15	328	418	304	.76	1.21	3.07	3.67
16	196	454	213	.62	.90	4.17	3.21
17	206	291	151	.40	1.47	4.13	3.53
18	230	317	119	.31	2.14	5.87	3.61
19	224	315	78	.14	4.45	12.47	5.08
20	161	424	50	0.00	R	R	R
21	81	307	148	0.00	R	R	R

CYCLE COMPOSITE BSHC = 1.019 GRAM/BHP HR
BSCO+ = 5.358 GRAM/BHP HR
BSNO2++ = 3.642 GRAM/BHP HR
BSHC + BSNO2++ = 4.661 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-001 DATE OF TEST' 1-04-73 TEST NO.2
ENGINE' MERCEDES OM636 SERIAL NO.' 636.941-019625

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.02	1.54	1.56	.015
2	1400	0.0	0.0	.04	2.91	2.95	.013
3	1400	7.6	2.0	.05	2.92	2.98	.018
4	1400	15.1	4.0	.06	2.88	2.94	.020
5	1400	22.7	6.1	.07	2.85	2.92	.025
6	1400	30.2	8.0	.08	2.85	2.93	.029
7	1400	37.8	10.1	.09	2.80	2.90	.034
8	1400	45.3	12.1	.11	2.80	2.91	.038
9	1400	52.9	14.1	.13	2.88	3.01	.045
10	1400	60.4	16.1	.14	2.76	2.90	.052
11	700	0.0	0.0	.02	1.51	1.53	.015
12	2400	61.7	28.2	.25	4.68	4.93	.054
13	2400	53.6	24.5	.22	4.66	4.88	.047
14	2400	46.3	21.2	.19	4.75	4.95	.041
15	2400	37.9	17.3	.17	4.75	4.92	.035
16	2400	30.9	14.1	.14	4.76	4.90	.030
17	2400	19.8	9.1	.12	4.86	4.98	.025
18	2400	15.4	7.0	.11	4.86	4.97	.023
19	2400	7.1	3.2	.09	4.87	4.96	.018
20	2400	0.0	0.0	.07	4.87	4.94	.014
21	700	0.0	0.0	.02	1.48	1.50	.016

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	231	606	154	0.00	R	R	R
2	164	401	64	0.00	R	R	R
3	149	281	137	.09	2.89	10.86	8.67
4	147	264	154	.18	1.42	5.07	4.87
5	169	270	216	.27	1.08	3.43	4.51
6	176	271	241	.35	.85	2.59	3.80
7	175	296	268	.44	.66	2.24	3.33
8	172	318	260	.53	.55	2.01	2.70
9	160	421	245	.62	.45	2.36	2.26
10	254	1485	224	.71	.60	7.03	1.74
11	162	423	229	0.00	R	R	R
12	130	1701	267	1.24	.30	7.82	2.02
13	166	455	303	1.08	.44	2.38	2.61
14	198	401	304	.93	.61	2.46	3.06
15	298	468	267	.76	1.12	3.50	3.28
16	316	397	230	.62	1.45	3.63	3.46
17	376	366	143	.40	2.73	5.30	3.39
18	399	380	106	.31	3.73	7.08	3.25
19	352	372	70	.14	7.11	14.95	4.61
20	272	476	30	0.00	R	R	R
21	140	353	138	0.00	R	R	R

CYCLE COMPOSITE BSHC = 1.221 GRAM/BHP HR
BSCO+ = 5.297 GRAM/BHP HR
BSNO2++= 3.286 GRAM/BHP HR
BSHC + BSNO2++= 4.506 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-001 DATE OF TEST' 1-05-73 TEST NO.3
ENGINE' MERCEDES OM636 SERIAL NO.' 636.941-019625

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.02	1.54	1.56	.013
2	1400	0.0	0.0	.03	2.87	2.90	.010
3	1400	7.6	2.0	.05	2.87	2.92	.017
4	1400	15.1	4.0	.06	2.90	2.96	.021
5	1400	22.7	6.1	.07	2.85	2.92	.025
6	1400	30.2	8.0	.08	2.82	2.90	.028
7	1400	37.8	10.1	.09	2.78	2.87	.032
8	1400	45.3	12.1	.11	2.80	2.90	.038
9	1400	52.9	14.1	.12	2.78	2.90	.045
10	1400	60.4	16.1	.14	2.68	2.82	.052
11	700	0.0	0.0	.02	1.53	1.55	.013
12	2400	61.7	28.2	.25	4.54	4.79	.055
13	2400	53.6	24.5	.23	4.66	4.89	.049
14	2400	46.3	21.2	.20	4.70	4.89	.042
15	2400	37.7	17.2	.17	4.69	4.87	.037
16	2400	30.9	14.1	.15	4.70	4.85	.033
17	2400	19.8	9.1	.12	4.70	4.82	.026
18	2400	15.5	7.1	.11	4.84	4.95	.023
19	2400	7.1	3.2	.09	4.83	4.92	.019
20	2400	0.0	0.0	.07	4.88	4.95	.014
21	700	0.0	0.0	.02	1.50	1.51	.012

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	270	464	133	0.00	R	R	R
2	338	557	47	0.00	R	R	R
3	267	266	126	.09	5.07	10.05	7.84
4	268	273	171	.18	2.60	5.29	5.43
5	237	220	205	.27	1.51	2.79	4.27
6	240	228	377	.35	1.14	2.16	5.86
7	236	236	305	.44	.89	1.77	3.75
8	216	258	293	.53	.69	1.63	3.04
9	206	321	287	.62	.56	1.74	2.55
10	332	1581	245	.71	.77	7.29	1.86
11	152	294	209	0.00	R	R	R
12	136	2427	273	1.24	.31	10.85	2.00
13	192	1027	294	1.08	.51	5.40	2.54
14	210	472	310	.93	.64	2.87	3.09
15	252	406	295	.76	.94	3.02	3.60
16	400	445	249	.62	1.82	4.02	3.70
17	440	383	177	.40	3.09	5.36	4.07
18	512	343	135	.31	4.73	6.31	4.09
19	504	395	80	.14	10.10	15.76	5.23
20	326	423	38	0.00	R	R	R
21	171	298	130	0.00	R	R	R

CYCLE COMPOSITE BSHC = 1.521 GRAM/BHP HR
BSCO+ = 5.937 GRAM/BHP HR
BSNO2++= 3.521 GRAM/BHP HR
BSHC + BSNO2++= 5.042 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-001 DATE OF TEST' 1-05-73 TEST NO.4
ENGINE' MERCEDES OM636 SERIAL NO.' 636.941-019625

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.02	1.52	1.54	.012
2	1400	0.0	0.0	.03	2.87	2.90	.011
3	1400	7.6	2.0	.05	2.91	2.96	.018
4	1400	15.1	4.0	.06	2.85	2.91	.021
5	1400	22.7	6.1	.07	2.81	2.88	.025
6	1400	30.2	8.0	.08	2.76	2.84	.028
7	1400	37.8	10.1	.10	2.78	2.87	.035
8	1400	45.3	12.1	.11	2.74	2.85	.039
9	1400	52.9	14.1	.12	2.70	2.83	.045
10	1400	60.4	16.1	.15	2.88	3.03	.051
11	700	0.0	0.0	.02	1.49	1.50	.012
12	2400	61.7	28.2	.25	4.62	4.87	.055
13	2400	53.6	24.5	.22	4.59	4.81	.049
14	2400	46.3	21.2	.19	4.57	4.77	.042
15	2400	37.9	17.3	.17	4.57	4.74	.037
16	2400	30.9	14.1	.15	4.57	4.72	.032
17	2400	19.8	9.1	.12	4.58	4.70	.027
18	2400	15.5	7.1	.11	4.68	4.79	.023
19	2400	7.1	3.2	.09	4.69	4.78	.020
20	2400	0.0	0.0	.06	4.69	4.75	.014
21	700	0.0	0.0	.02	1.39	1.41	.014

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	120	385	154	0.00	R	R	R
2	133	279	60	0.00	R	R	R
3	162	265	128	.09	3.12	10.17	8.04
4	183	267	164	.18	1.74	5.07	5.12
5	185	248	205	.27	1.16	3.10	4.22
6	206	284	248	.35	.96	2.64	3.78
7	194	284	263	.44	.73	2.13	3.23
8	164	261	287	.53	.51	1.62	2.93
9	200	470	252	.62	.53	2.47	2.18
10	260	1486	244	.71	.65	7.36	1.98
11	131	339	181	0.00	R	R	R
12	112	2475	277	1.24	.26	11.25	2.07
13	172	735	307	1.08	.45	3.80	2.61
14	198	413	325	.93	.59	2.44	3.16
15	282	453	298	.76	1.02	3.26	3.51
16	380	496	277	.62	1.68	4.36	4.00
17	488	373	186	.40	3.34	5.09	4.17
18	556	379	136	.31	4.97	6.75	3.99
19	480	369	86	.14	9.35	14.32	5.48
20	358	491	41	0.00	R	R	R
21	103	386	147	0.00	R	R	R

CYCLE COMPOSITE BSHC = 1.345 GRAM/BHP HR
BSCO+ = 5.802 GRAM/BHP HR
BSNO2++= 3.432 GRAM/BHP HR
BSHC + BSNO2++= 4.777 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-001 DATE OF TEST' 1-08-73 TEST NO.5
ENGINE' MERCEDES OM636 SERIAL NO.' 636.941-019625

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.02	1.58	1.60	.013
2	1400	0.0	0.0	.04	3.00	3.04	.014
3	1400	7.9	2.1	.05	2.92	2.97	.018
4	1400	15.8	4.2	.06	2.90	2.97	.021
5	1400	23.6	6.3	.07	2.89	2.96	.025
6	1400	31.5	8.4	.09	2.88	2.97	.031
7	1400	39.4	10.5	.09	2.92	3.01	.033
8	1400	47.3	12.6	.11	2.83	2.94	.039
9	1400	55.1	14.7	.13	2.91	3.04	.045
10	1400	63.0	16.8	.14	2.77	2.91	.051
11	700	0.0	0.0	.02	1.51	1.53	.013
12	2400	64.3	29.4	.26	4.65	4.91	.055
13	2400	56.5	25.8	.23	4.61	4.84	.049
14	2400	48.3	22.1	.19	4.71	4.90	.040
15	2400	40.4	18.5	.16	4.77	4.93	.034
16	2400	32.2	14.7	.15	4.77	4.92	.032
17	2400	24.3	11.1	.12	4.82	4.95	.026
18	2400	16.1	7.4	.10	4.93	5.03	.021
19	2400	8.0	3.7	.09	4.93	5.02	.018
20	2400	0.0	0.0	.07	4.94	5.01	.015
21	700	0.0	0.0	.02	1.50	1.52	.011

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	280	477	160	0.00	R	R	R
2	206	347	38	0.00	R	R	R
3	177	236	91	.09	3.31	8.78	5.58
4	165	173	162	.18	1.54	3.22	4.94
5	188	192	199	.28	1.17	2.37	4.04
6	174	168	236	.37	.81	1.56	3.61
7	168	180	261	.46	.64	1.36	3.24
8	140	186	255	.55	.43	1.14	2.57
9	140	196	250	.65	.38	1.06	2.23
10	200	774	212	.74	.46	3.53	1.59
11	108	335	143	0.00	R	R	R
12	120	1752	268	1.29	.26	7.69	1.93
13	140	586	285	1.14	.35	2.89	2.31
14	200	352	305	.97	.59	2.05	2.92
15	260	380	261	.81	.92	2.67	3.01
16	432	384	193	.65	1.91	3.38	2.79
17	376	289	165	.49	2.21	3.39	3.19
18	500	294	104	.32	4.50	5.27	3.07
19	463	357	63	.16	8.39	12.87	3.74
20	242	448	32	0.00	R	R	R
21	145	349	106	0.00	R	R	R

CYCLE COMPOSITE BSHC = 1.235 GRAM/BHP HR
BSCO+ = 4.281 GRAM/BHP HR
BSNO2++= 2.964 GRAM/BHP HR
BSHC + BSNO2++= 4.199 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-001 DATE OF TEST' 1-09-73 TEST NO.6
ENGINE' MERCEDES SERIAL NO.' 636.941-019625

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.02	1.56	1.58	.013
2	1400	0.0	0.0	.04	2.93	2.97	.013
3	1400	7.9	2.1	.05	2.92	2.98	.018
4	1400	15.8	4.2	.06	2.92	2.99	.022
5	1400	23.6	6.3	.07	2.89	2.96	.025
6	1400	31.5	8.4	.09	2.87	2.96	.031
7	1400	39.4	10.5	.10	2.87	2.97	.034
8	1400	47.3	12.6	.11	2.82	2.93	.041
9	1400	55.1	14.7	.13	2.81	2.93	.045
10	1400	63.0	16.8	.14	2.73	2.88	.053
11	700	0.0	0.0	.02	1.52	1.54	.013
12	2400	64.3	29.4	.25	4.59	4.84	.055
13	2400	56.5	25.8	.22	4.57	4.79	.049
14	2400	48.3	22.1	.19	4.67	4.86	.041
15	2400	40.4	18.5	.17	4.67	4.84	.036
16	2400	32.2	14.7	.15	4.67	4.82	.031
17	2400	24.3	11.1	.12	4.78	4.91	.026
18	2400	16.1	7.4	.11	4.78	4.89	.022
19	2400	8.3	3.8	.09	4.79	4.88	.019
20	2400	0.0	0.0	.07	4.89	4.96	.015
21	700	0.0	0.0	.02	1.45	1.47	.014

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	103	412	116	0.00	R	R	R
2	109	310	55	0.00	R	R	R
3	133	294	98	.09	2.49	10.96	6.02
4	132	264	134	.18	1.24	4.94	4.11
5	140	242	195	.28	.87	3.00	3.95
6	151	260	239	.37	.70	2.41	3.64
7	132	248	279	.46	.49	1.84	3.40
8	120	280	291	.55	.37	1.71	2.92
9	115	266	268	.65	.30	1.39	2.31
10	144	827	244	.74	.33	3.73	1.80
11	104	425	151	0.00	R	R	R
12	96	1557	296	1.29	.21	6.74	2.10
13	142	586	317	1.14	.35	2.86	2.54
14	180	351	331	.97	.52	2.03	3.15
15	260	383	296	.81	.90	2.64	3.35
16	300	332	239	.65	1.30	2.86	3.38
17	404	317	189	.49	2.36	3.68	3.61
18	536	279	121	.32	4.69	4.86	3.46
19	532	321	77	.17	9.06	10.91	4.29
20	300	372	40	0.00	R	R	R
21	130	222	109	0.00	R	R	R

CYCLE COMPOSITE BSHC = 1.119 GRAM/BHP HR
BSCO+ = 4.180 GRAM/BHP HR
BSNO2++= 3.198 GRAM/BHP HR
BSHC + BSNO2++= 4.317 GRAM/BHP HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-001 DATE OF TEST' 1-09-73 TEST NO.7
ENGINE' MERCEDES OM636 SERIAL NO.' 636-941-019625

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.02	1.49	1.51	.013
2	1400	0.0	0.0	.04	2.88	2.91	.013
3	1400	7.9	2.1	.05	2.88	2.93	.019
4	1400	15.8	4.2	.06	2.83	2.89	.022
5	1400	23.6	6.3	.07	2.81	2.88	.024
6	1400	31.5	8.4	.09	2.83	2.92	.031
7	1400	39.4	10.5	.10	2.78	2.88	.035
8	1400	47.3	12.6	.11	2.78	2.88	.039
9	1400	55.1	14.7	.13	2.77	2.90	.047
10	1400	63.0	16.8	.14	2.77	2.91	.052
11	700	0.0	0.0	.02	1.48	1.50	.015
12	2400	64.3	29.4	.25	4.60	4.85	.054
13	2400	56.5	25.8	.23	4.57	4.80	.051
14	2400	48.3	22.1	.19	4.66	4.85	.040
15	2400	40.4	18.5	.16	4.66	4.82	.035
16	2400	32.2	14.7	.15	4.76	4.91	.031
17	2400	24.3	11.1	.13	4.76	4.89	.027
18	2400	16.1	7.4	.11	4.77	4.87	.022
19	2400	8.3	3.8	.09	4.88	4.97	.018
20	2400	0.0	0.0	.07	4.89	4.96	.014
21	700	0.0	0.0	.02	1.45	1.47	.014

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	71	360	145	0.00	R	R	R
2	118	373	59	0.00	R	R	R
3	128	297	117	.09	2.36	10.90	7.05
4	135	265	172	.18	1.23	4.79	5.13
5	146	265	206	.28	.88	3.19	4.08
6	150	274	249	.37	.69	2.50	3.74
7	132	260	291	.46	.48	1.87	3.44
8	132	281	302	.55	.40	1.69	2.99
9	136	300	261	.65	.35	1.56	2.22
10	202	931	230	.74	.46	4.24	1.72
11	102	359	149	0.00	R	R	R
12	84	1842	287	1.29	.18	7.99	2.04
13	110	536	288	1.14	.27	2.62	2.32
14	180	426	317	.97	.52	2.46	3.01
15	232	417	312	.81	.80	2.86	3.52
16	294	397	274	.65	1.30	3.48	3.95
17	372	363	194	.49	2.16	4.20	3.68
18	440	220	122	.32	3.84	3.82	3.47
19	408	369	69	.17	7.09	12.77	3.92
20	304	462	36	0.00	R	R	R
21	144	309	103	0.00	R	R	R

CYCLE COMPOSITE BSHC = 1.033 GRAM/BHP HR
BSCO+ = 4.579 GRAM/BHP HR
BSNO2++= 3.234 GRAM/BHP HR
BSHC + BSNO2++= 4.267 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 10-11-72 TEST NO.1
ENGINE' PERKINS 4.236 SERIAL NO.'236UE1943

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	2.6	.3	.01	2.61	2.62	.004
2	1450	2.6	.7	.06	6.41	6.47	.009
3	1450	24.9	6.9	.07	6.41	6.48	.011
4	1450	47.3	13.0	.10	6.37	6.47	.016
5	1450	70.9	19.6	.11	6.28	6.39	.018
6	1450	93.2	25.7	.16	6.21	6.37	.026
7	1450	119.5	33.0	.20	6.19	6.39	.033
8	1450	143.1	39.5	.23	6.06	6.29	.038
9	1450	164.1	45.3	.29	6.01	6.30	.048
10	1450	182.5	50.4	.34	5.95	6.29	.058
11	640	2.6	.3	.01	2.56	2.57	.003
12	2400	165.4	75.6	.50	9.67	10.17	.052
13	2400	145.7	66.6	.43	9.59	10.02	.044
14	2400	124.7	57.0	.35	9.59	9.94	.037
15	2400	102.4	46.8	.29	9.62	9.91	.031
16	2400	82.7	37.8	.26	9.65	9.91	.027
17	2400	61.7	28.2	.21	9.67	9.88	.022
18	2400	40.7	18.6	.17	9.65	9.82	.018
19	2400	21.0	9.6	.13	9.67	9.81	.014
20	2400	2.6	1.2	.09	9.67	9.76	.009
21	640	1.3	.2	.01	2.43	2.44	.003

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	280	187	97	.02	30.28	40.36	34.26
2	238	248	106	.03	28.03	58.28	40.86
3	194	273	187	.30	2.41	6.75	7.60
4	176	321	346	.57	1.15	4.18	7.40
5	152	256	591	.86	.66	2.20	8.35
6	140	192	847	1.13	.46	1.25	9.05
7	138	153	1245	1.45	.35	.78	10.42
8	132	175	1550	1.74	.28	.73	10.66
9	112	661	1919	1.99	.21	2.42	11.52
10	78	4621	1877	2.22	.13	15.18	10.13
11	252	227	138	.02	26.70	47.81	47.82
12	38	3431	1966	3.33	.07	12.14	11.43
13	86	754	1911	2.93	.17	2.98	12.42
14	78	223	1611	2.51	.18	1.02	12.14
15	108	214	1073	2.06	.30	1.19	9.82
16	132	264	803	1.66	.46	1.82	9.09
17	146	329	551	1.24	.68	3.03	8.34
18	180	357	355	.82	1.25	4.96	8.10
19	238	347	227	.42	3.21	9.32	10.01
20	328	337	146	.05	35.22	72.20	51.40
21	324	264	107	.01	65.18	105.88	70.59

CYCLE COMPOSITE BSHC = .576 GRAM/BHP HR
BSCO+ = 4.976 GRAM/BHP HR
BSNO2++= 10.679 GRAM/BHP HR
BSHC + BSNO2++= 11.255 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 10-11-72 TEST NO.2
ENGINE' PERKINS 4.236 SERIAL NO.'236UE1943

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	2.6	.3	.01	2.60	2.61	.005
2	1450	2.6	.7	.04	6.28	6.32	.007
3	1450	24.9	6.9	.07	6.35	6.42	.011
4	1450	47.3	13.0	.10	6.76	6.86	.015
5	1450	70.9	19.6	.12	6.28	6.40	.020
6	1450	93.2	25.7	.16	6.15	6.31	.026
7	1450	119.5	33.0	.18	6.13	6.31	.030
8	1450	143.1	39.5	.23	6.07	6.30	.038
9	1450	164.1	45.3	.28	6.01	6.29	.047
10	1450	182.5	50.4	.33	5.99	6.32	.056
11	640	2.6	.3	.01	2.71	2.72	.004
12	2400	165.4	75.6	.50	9.62	10.12	.052
13	2400	145.7	66.6	.40	9.52	9.92	.042
14	2400	124.7	57.0	.36	9.52	9.88	.038
15	2400	102.4	46.8	.30	9.49	9.79	.032
16	2400	82.7	37.8	.24	9.52	9.76	.025
17	2400	61.7	28.2	.20	9.52	9.72	.021
18	2400	40.7	18.6	.16	9.55	9.71	.016
19	2400	21.0	9.6	.10	9.62	9.72	.011
20	2400	2.6	1.2	.04	9.65	9.69	.004
21	640	1.3	.2	.01	2.43	2.44	.003

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	320	315	65	.02	34.50	67.60	23.10
2	250	288	85	.03	28.79	66.04	32.03
3	206	311	182	.30	2.53	7.62	7.34
4	192	334	338	.57	1.33	4.62	7.67
5	178	268	515	.86	.77	2.31	7.28
6	166	191	825	1.13	.54	1.23	8.74
7	152	165	1205	1.45	.38	.83	9.96
8	130	223	1663	1.74	.27	.93	11.46
9	134	1018	2004	1.99	.25	3.72	12.02
10	150	4819	1923	2.22	.25	15.90	10.42
11	264	277	154	.02	29.62	61.91	56.64
12	50	3357	1961	3.33	.09	11.82	11.34
13	78	622	1667	2.93	.15	2.44	10.73
14	70	269	1664	2.51	.16	1.23	12.46
15	100	249	1168	2.06	.28	1.37	10.56
16	128	265	557	1.66	.44	1.80	6.21
17	132	329	549	1.24	.60	2.99	8.18
18	170	358	392	.82	1.17	4.91	8.83
19	226	336	223	.42	3.02	8.96	9.74
20	292	302	144	.05	31.13	64.23	50.28
21	288	252	105	.01	57.90	100.78	68.87

CYCLE COMPOSITE BSHC = .585 GRAM/BHP HR
BSCO+ = 5.125 GRAM/BHP HR
BSNO2++= 10.417 GRAM/BHP HR
BSHC + BSNO2++= 11.002 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 10-13-72 TEST NO.3
ENGINE' PERKINS 4.236 SERIAL NO.' 236UE1943

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	2.6	.3	.02	2.65	2.67	.006
2	1450	2.6	.7	.05	6.47	6.52	.007
3	1450	24.9	6.9	.08	6.49	6.57	.012
4	1450	46.0	12.7	.10	6.56	6.66	.015
5	1450	73.5	20.3	.13	6.33	6.46	.021
6	1450	95.8	26.5	.16	6.26	6.42	.026
7	1450	118.2	32.6	.20	6.24	6.44	.033
8	1450	143.1	39.5	.24	6.21	6.45	.038
9	1450	165.4	45.7	.28	6.15	6.43	.046
10	1450	186.4	51.5	.34	6.13	6.47	.055
11	640	2.6	.3	.01	2.76	2.77	.005
12	2400	166.8	76.2	.51	9.58	10.09	.054
13	2400	145.7	66.6	.42	9.87	10.29	.043
14	2400	126.0	57.6	.36	9.90	10.26	.037
15	2400	105.0	48.0	.31	9.90	10.21	.031
16	2400	85.3	39.0	.26	9.87	10.13	.026
17	2400	63.0	28.8	.22	9.96	10.18	.022
18	2400	43.3	19.8	.17	9.96	10.13	.017
19	2400	21.0	9.6	.13	9.96	10.09	.013
20	2400	3.9	1.8	.10	10.00	10.10	.010
21	640	2.6	.3	.01	2.52	2.53	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	316	263	85	.02	34.76	57.57	30.57
2	228	275	85	.03	27.05	65.00	32.91
3	224	336	201	.30	2.82	8.42	8.28
4	222	359	304	.56	1.54	4.95	6.88
5	200	267	548	.89	.84	2.24	7.54
6	208	204	837	1.16	.67	1.30	8.78
7	148	177	1228	1.44	.39	.92	10.48
8	148	210	1470	1.74	.32	.90	10.36
9	184	541	1789	2.01	.34	2.00	10.89
10	100	4768	1943	2.26	.17	15.75	10.55
11	272	289	124	.02	31.12	65.91	46.35
12	60	3001	2014	3.35	.10	10.45	11.53
13	132	669	1887	2.93	.27	2.72	12.60
14	90	246	1531	2.53	.21	1.16	11.78
15	98	237	1168	2.11	.28	1.33	10.73
16	142	289	823	1.72	.49	1.97	9.23
17	146	379	536	1.27	.68	3.52	8.18
18	184	408	346	.87	1.24	5.50	7.64
19	240	385	221	.42	3.33	10.66	10.03
20	308	337	142	.08	22.81	49.77	34.46
21	304	302	104	.02	31.77	62.83	35.53

CYCLE COMPOSITE BSHC = .645 GRAM/BHP HR
BSCO+ = 4.944 GRAM/BHP HR
BSNO2++= 10.621 GRAM/BHP HR
BSHC + BSNO2++= 11.267 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT: 11-2869-01 DATE OF TEST: 10-13-72 TEST NO.4
ENGINE: PERKINS 4.236 SERIAL NO.: 236UE1943

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	2.6	.3	.01	2.66	2.67	.006
2	1450	2.6	.7	.04	6.46	6.50	.006
3	1450	24.9	6.9	.07	6.39	6.46	.011
4	1450	47.3	13.0	.09	6.39	6.48	.014
5	1450	70.9	19.6	.13	6.31	6.44	.021
6	1450	94.5	26.1	.16	6.24	6.40	.026
7	1450	119.5	33.0	.18	6.17	6.35	.029
8	1450	143.1	39.5	.23	6.17	6.40	.038
9	1450	166.8	46.0	.25	6.06	6.31	.041
10	1450	185.1	51.1	.34	6.01	6.35	.057
11	640	2.6	.3	.01	2.62	2.63	.004
12	2400	164.1	75.0	.51	9.71	10.22	.052
13	2400	145.7	66.6	.43	9.52	9.95	.045
14	2400	127.4	58.2	.38	9.62	10.00	.040
15	2400	105.0	48.0	.31	9.56	9.87	.032
16	2400	85.3	39.0	.25	9.52	9.77	.027
17	2400	63.0	28.8	.22	9.62	9.84	.023
18	2400	42.0	19.2	.18	9.62	9.80	.018
19	2400	22.3	10.2	.13	9.67	9.80	.014
20	2400	2.6	1.2	.09	9.65	9.74	.009
21	640	2.6	.3	.01	2.50	2.51	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	320	250	101	.02	35.31	55.00	36.58
2	260	238	91	.03	30.78	56.11	35.44
3	188	260	197	.30	2.33	6.42	7.96
4	196	296	383	.57	1.29	3.87	8.21
5	194	231	657	.86	.84	2.00	9.33
6	202	155	941	1.15	.65	1.00	9.98
7	194	130	1306	1.45	.49	.66	10.86
8	146	163	1657	1.74	.31	.69	11.61
9	182	559	1998	2.03	.33	2.01	11.83
10	156	4744	1929	2.25	.26	15.51	10.36
11	240	213	121	.02	26.05	46.09	42.94
12	32	2890	1972	3.30	.06	10.35	11.61
13	124	654	2027	2.93	.24	2.57	13.08
14	86	245	1751	2.56	.20	1.11	13.00
15	130	237	1183	2.11	.35	1.28	10.51
16	166	276	815	1.72	.55	1.82	8.83
17	160	392	545	1.27	.72	3.52	8.04
18	198	407	347	.84	1.33	5.47	7.64
19	240	373	226	.45	3.04	9.42	9.38
20	318	338	139	.05	34.07	72.06	48.68
21	320	289	92	.02	33.18	59.67	31.11

CYCLE COMPOSITE BSHC = .651 GRAM/BHP HR
BSCO+ = 4.706 GRAM/BHP HR
BSNO2++= 11.059 GRAM/BHP HR
BSHC + BSNO2++= 11.710 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 10-18-72 TEST NO.5
ENGINE' PERKINS 4.236 SERIAL NO.' 236UE1943

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	2.6	.3	.02	2.54	2.56	.007
2	1450	2.6	.7	.05	6.51	6.56	.007
3	1450	23.6	6.5	.08	6.58	6.66	.012
4	1450	48.6	13.4	.11	6.40	6.51	.017
5	1450	69.6	19.2	.14	6.75	6.89	.021
6	1450	95.8	26.5	.18	6.22	6.40	.029
7	1450	116.9	32.3	.22	6.22	6.44	.036
8	1450	137.9	38.1	.25	5.66	5.91	.044
9	1450	165.4	45.7	.30	5.64	5.94	.053
10	1450	181.2	50.0	.34	6.23	6.57	.055
11	640	3.9	.5	.01	2.57	2.58	.005
12	2400	166.8	76.2	.51	9.58	10.09	.053
13	2400	145.7	66.6	.42	9.71	10.13	.043
14	2400	126.0	57.6	.36	9.67	10.03	.037
15	2400	105.0	48.0	.31	9.80	10.11	.032
16	2400	85.3	39.0	.26	9.83	10.09	.027
17	2400	63.0	28.8	.23	9.87	10.10	.023
18	2400	42.0	19.2	.17	9.87	10.04	.017
19	2400	21.0	9.6	.13	9.90	10.03	.014
20	2400	3.9	1.8	.10	9.93	10.03	.010
21	640	2.6	.3	.02	2.52	2.54	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	320	275	68	.02	33.75	57.86	23.36
2	302	288	78	.03	36.05	68.46	30.41
3	276	336	177	.29	3.72	9.01	7.82
4	272	345	348	.59	1.74	4.40	7.30
5	266	280	570	.85	1.26	2.64	8.83
6	260	166	921	1.16	.63	1.05	9.63
7	254	152	1216	1.42	.67	.80	10.50
8	150	242	1680	1.67	.31	.99	11.27
9	216	1265	1936	2.01	.37	4.33	10.88
10	148	5247	1930	2.20	.26	18.13	10.96
11	250	250	118	.03	17.76	35.44	27.49
12	60	3276	1874	3.35	.10	11.41	10.72
13	150	520	1829	2.93	.30	2.08	12.02
14	94	211	1494	2.53	.22	.97	11.24
15	110	226	1178	2.11	.31	1.25	10.72
16	152	289	797	1.72	.52	1.96	8.91
17	164	353	517	1.27	.76	3.25	7.83
18	198	370	325	.84	1.37	5.09	7.34
19	260	347	208	.42	3.59	9.55	9.40
20	320	337	138	.08	23.53	49.42	33.09
21	324	314	97	.02	33.90	65.42	33.35

CYCLE COMPOSITE BSHC = .739 GRAM/BHP HR
BSCO+ = 5.288 GRAM/BHP HR
BSNO2++= 10.499 GRAM/BHP HR
BSHC + BSNO2++= 11.238 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

PROJECT' 11-2869-01 DATE OF TEST' 10-18-72 TEST NO.6
ENGINE' PERKINS 4.236 SERIAL NO.' 236UE1943

MODE	ENGINE SPEED RPM	TORQUE LB-FT	POWER BHP	FUEL FLOW LB/MIN	AIR FLOW LB/MIN	EXHAUST FLOW LB/MIN	FUEL AIR RATIO
1	640	2.6	.3	.01	2.52	2.53	.005
2	1450	2.6	.7	.04	6.50	6.54	.007
3	1450	24.9	6.9	.07	6.43	6.50	.011
4	1450	46.0	12.7	.10	6.45	6.55	.016
5	1450	68.3	18.8	.13	6.34	6.47	.021
6	1450	95.8	26.5	.18	6.27	6.45	.029
7	1450	119.5	33.0	.23	6.18	6.41	.037
8	1450	140.5	38.8	.26	6.14	6.40	.042
9	1450	165.4	45.7	.29	6.10	6.39	.048
10	1450	181.2	50.0	.34	5.92	6.26	.058
11	640	1.3	.2	.01	2.70	2.71	.004
12	2400	165.4	75.6	.51	9.61	10.12	.053
13	2400	147.1	67.2	.43	9.27	9.70	.046
14	2400	127.4	58.2	.37	9.37	9.74	.039
15	2400	105.0	48.0	.31	9.67	9.98	.032
16	2400	82.7	37.8	.27	9.67	9.94	.028
17	2400	61.7	28.2	.21	9.80	10.01	.022
18	2400	42.0	19.2	.18	9.83	10.01	.018
19	2400	21.0	9.6	.13	9.90	10.03	.013
20	2400	3.9	1.8	.09	9.90	9.99	.009
21	640	2.6	.3	.01	2.51	2.52	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED BHP	BSHC G/HP HR	BSCO+ G/HP HR	BSNO2++ G/HP HR
1	316	263	68	.02	33.02	54.80	23.32
2	298	275	68	.03	35.50	65.34	26.52
3	272	336	179	.30	3.39	8.35	7.29
4	262	346	317	.56	1.79	4.70	7.06
5	254	268	548	.83	1.15	2.42	8.12
6	256	190	854	1.16	.82	1.22	8.99
7	246	175	1305	1.45	.63	.89	10.95
8	192	303	1778	1.71	.42	1.31	12.67
9	254	1227	2038	2.01	.47	4.52	12.32
10	196	5326	1991	2.20	.32	17.54	10.77
11	232	251	130	.01	51.87	111.87	94.81
12	62	1846	2039	3.33	.11	6.50	11.79
13	160	801	2023	2.96	.30	3.04	12.61
14	108	233	1668	2.56	.24	1.03	12.05
15	122	213	1217	2.11	.33	1.17	10.93
16	150	264	857	1.66	.52	1.82	9.73
17	168	341	534	1.24	.79	3.19	8.20
18	208	382	372	.84	1.43	5.23	8.36
19	270	348	231	.42	3.72	9.55	10.42
20	310	312	149	.08	22.72	45.56	35.64
21	314	276	98	.02	32.68	57.25	33.44

CYCLE COMPOSITE BSHC = .757 GRAM/BHP HR
BSCO+ = 4.712 GRAM/BHP HR
BSNO2++= 11.112 GRAM/BHP HR
BSHC + BSNO2++= 11.870 GRAM/BHP HR

\+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 75 GRAINS WATER PER LB. DRY AIR

APPENDIX E

GRAPHICAL PRESENTATION OF EMISSIONS FROM GASOLINE ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

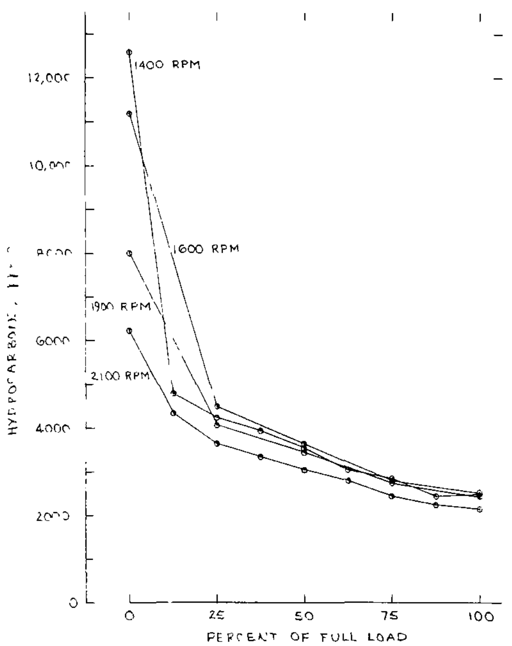

FIGURE E-1 HYDROCARBON EMISSIONS FROM A FORD G-5000 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

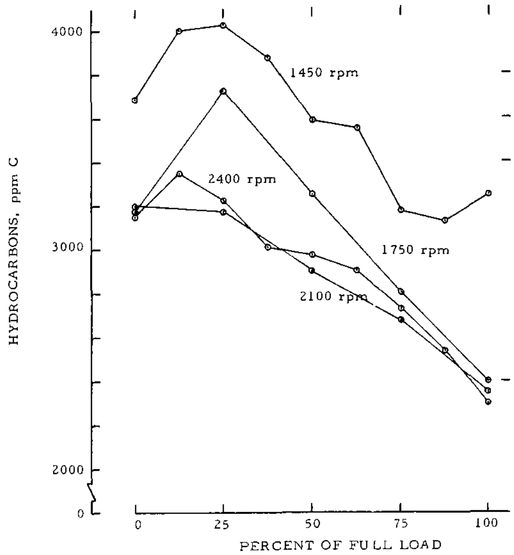

FIGURE E-2. HYDROCARBON EMISSIONS FROM A HERCULES G-2300 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

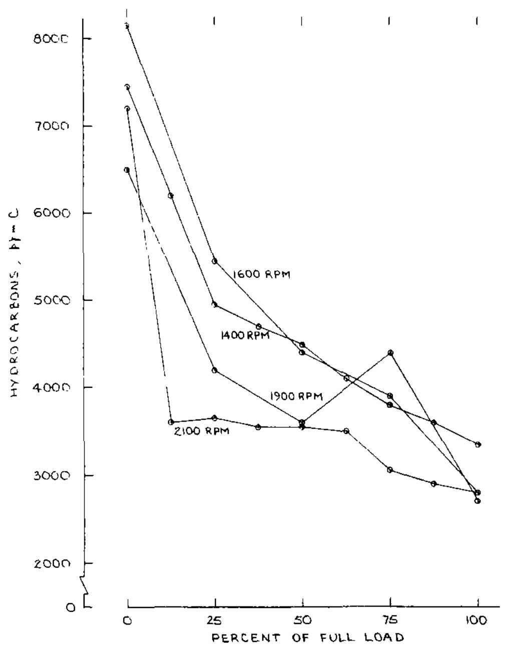

FIGURE E-3. HYDROCARBON EMISSIONS FROM A J.I. CASE 159 G ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

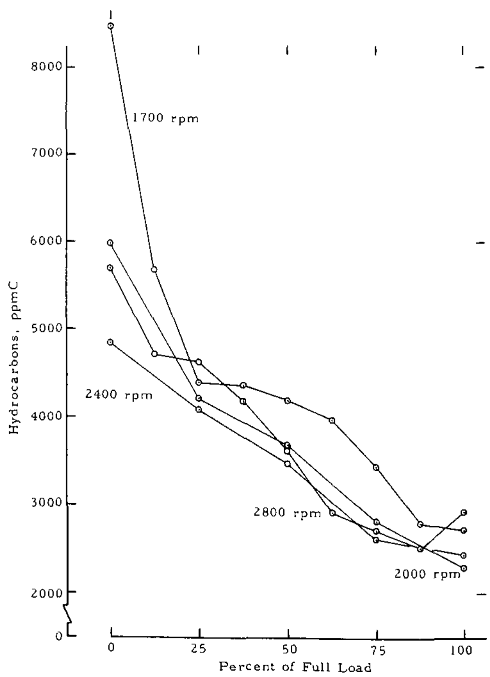

FIGURE E-4. HYDROCARBON EMISSIONS FROM A WISCONSIN VH4D ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

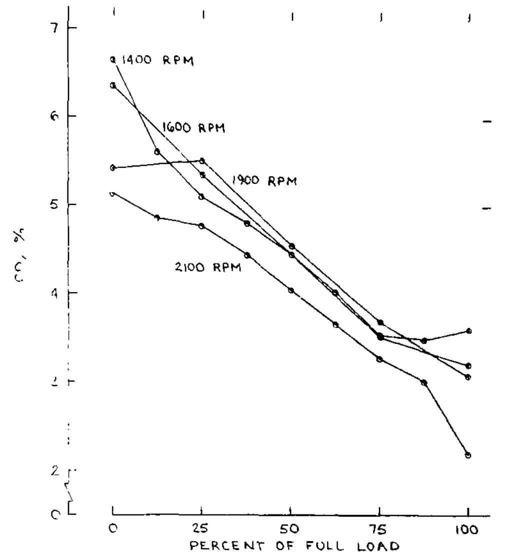

FIGURE E-5. CARBON MONOXIDE EMISSIONS FROM A FORD G5000 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

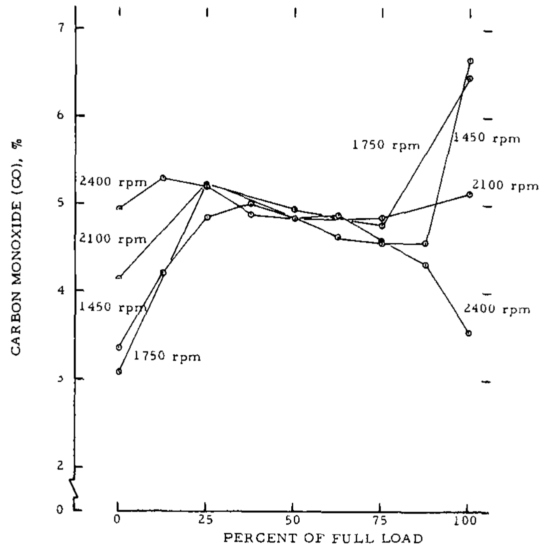

FIGURE E-6. CARBON MONOXIDE EMISSIONS FROM A HERCULES G-2300 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

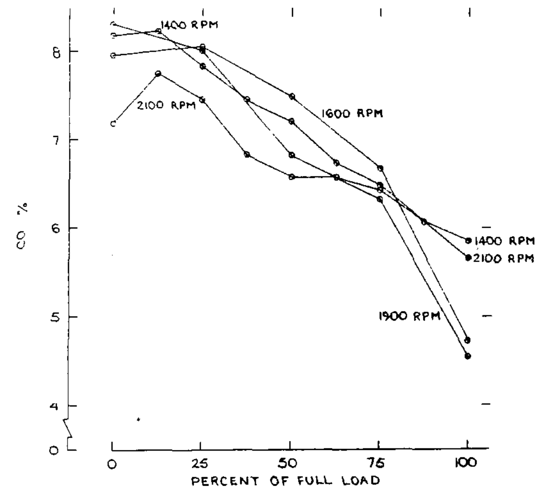

FIGURE E-7 CARBON MONOXIDE EMISSIONS FROM A J.I. CASE 159 G ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

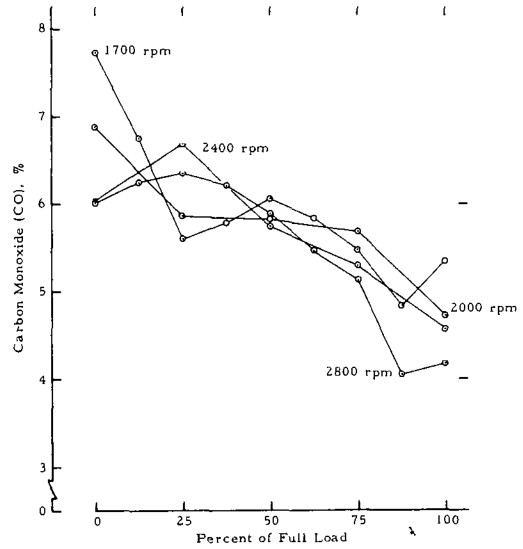

FIGURE E-8. CARBON MONOXIDE EMISSIONS FROM A WISCONSIN VH4D ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

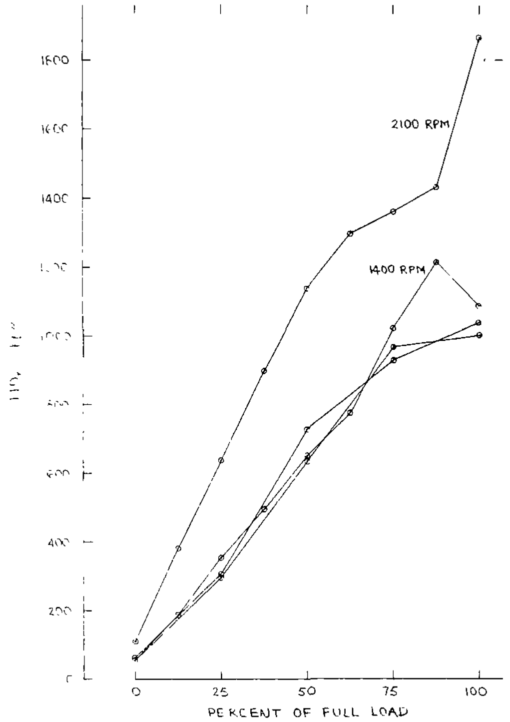

FIGURE E-9. OXIDES OF NITROGEN EMISSIONS FROM A FORD [illegible] ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

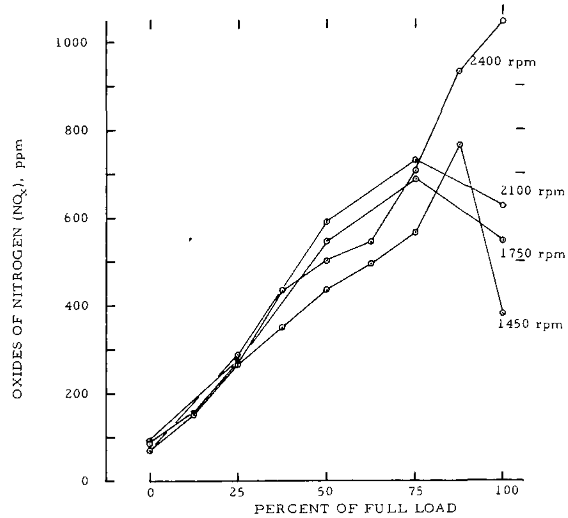

FIGURE E-10. OXIDES OF NITROGEN EMISSIONS FROM A HERCULES G-2300 ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

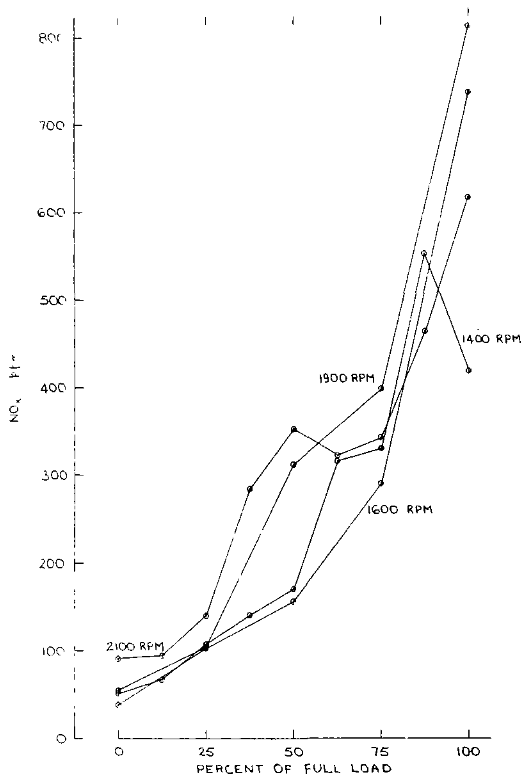

FIGURE E-11. OXIDES OF NITROGEN EMISSIONS FROM A J.I. CASE 159 G ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

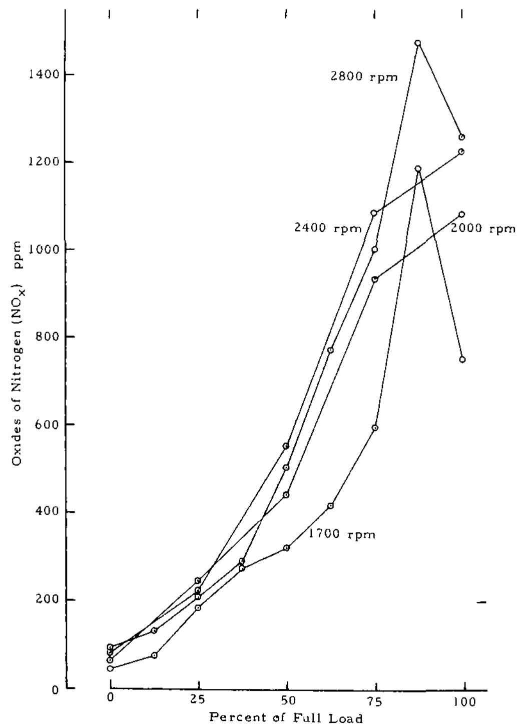

FIGURE E-12. OXIDES OF NITROGEN EMISSIONS FROM A WISCONSIN VH4D ENGINE AS A FUNCTION OF LOAD AT FOUR SPEEDS

APPENDIX F

TABULAR PERFORMANCE AND EMISSIONS DATA ON GASOLINE ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP., °F INTAKE AIR	EXHAUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	615	——	3.2	68	458	0.0	0.0	19.0	6900	336	1.95	9.68	195	73	66	2.1
2	1400	——	7.2	72	656	0.2	0.0	19.2	12,000	584	6.52	7.50	122	60	50	1.7
3	1400	6.3	10.2	77	814	0.4	0.0	17.9	4600	313	5.41	9.02	317	245	227	1.7
4	1400	13.0	12.9	78	847	0.5	0.0	15.9	4200	199	5.42	8.93	416	344	331	1.2
5	1400	18.9	15.1	80	879	0.7	0.0	13.8	4300	105	5.18	9.12	466	440	430	1.2
6	1400	25.6	17.4	75	987	1.1	0.0	11.9	3500	136	4.60	9.69	675	645	612	1.2
7	1400	31.8	19.4	76	1049	1.4	0.0	9.8	3350	126	4.39	9.89	898	827	710	1.1
8	1400	38.2	22.3	77	1108	1.8	0.1	7.4	2900	115	3.84	10.30	1139	990	969	1.1
9	1400	44.4	25.4	79	1170	1.8	0.1	5.1	2250	96	3.16	10.73	1236	1165	1143	1.0
10	1400	52.8	28.6	81	1225	2.8	0.2	2.1	2500	86	2.99	10.75	1113	1163	1146	1.0
11	660	——	3.1	78	722	0.1	0.0	19.3	6000	284	2.17	10.65	123	70	65	1.9
12	2100	70.4	37.7	76	1274	4.8	0.4	3.1	2200	147	2.29	11.39	1907	1946	1773	0.8
13	2100	58.8	30.7	77	1231	3.5	0.2	7.1	2300	75	3.08	10.74	1610	1490	1469	0.7
14	2100	50.4	28.5	77	1196	3.0	0.2	9.0	2450	85	3.42	10.61	1500	1379	1326	0.8
15	2100	42.0	25.1	77	1154	2.2	0.1	11.2	2950	95	3.87	10.47	1495	1310	1138	0.8
16	2100	33.6	20.4	77	1112	1.8	0.1	13.1	3100	115	4.08	10.18	1264	1140	1075	0.8
17	2100	25.2	18.4	76	1025	1.3	0.1	15.4	3350	136	4.59	9.87	1013	958	837	0.7
18	2100	16.8	15.8	78	989	0.9	0.1	16.5	3600	135	4.81	9.75	782	696	643	0.9
19	2100	8.4	12.0	77	923	0.6	0.0	18.5	3250	136	4.93	9.48	366	343	322	1.2
20	2100	——	9.7	77	882	0.4	0.0	19.6	4000	179	5.08	8.60	156	130	112	2.1
21	645	——	3.2	77	716	0.1	0.0	19.7	7000	320	2.71	9.87	89	61	56	2.3
22	1450	——	3.3	82	435	0.0	0.0	21.4	32,500	3380	2.18	6.07	93	10.9	6.8	8.6
23	2150	——	3.3	73	413	0.0	0.0	[illegible]	[illegible]	[illegible]	2.11	4.00	23	5.1	4.8	10.2

ENGINE FORD G5000   DATE 3/28/72   WET BULB TEMP., °F 56

RUN 1   BAROMETER, in Hg 29.08   DRY BULB TEMP., °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP., °F INTAKE AIR	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	620	———	3.1	66	591	0.1	0.0	19.4	6550	169	2.53	9.83	89	70	65	2.3
2	1400	———	7.1	67	677	0.2	0.0	19.4	11,100	290	6.34	7.55	88	58	52	1.9
3	1400	6.6	8.9	70	727	0.3	0.0	17.9	4350	243	5.46	8.63	211	189	184	1.5
4	1400	13.3	11.1	70	842	0.4	0.0	16.1	4400	178	5.05	8.67	379	348	344	1.6
5	1400	20.0	14.4	71	892	0.8	0.0	13.9	3900	157	4.71	8.94	595	503	486	1.5
6	1400	26.6	16.2	72	963	0.9	[illegible]	11.9	3700	157	4.49	9.12	621	589	563	1.5
7	1400	33.2	18.1	71	1050	1.3	0.0	9.3	3150	126	4.04	9.35	930	755	723	1.5
8	1400	39.9	22.5	74	1108	1.6	0.1	7.2	3000	116	3.61	9.73	1205	960	939	1.4
9	1400	46.6	24.5	75	1185	2.3	0.1	4.7	2600	96	3.08	10.13	1335	1220	1188	1.1
10	1400	52.8	27.1	75	1217	2.7	0.4	2.0	2600	96	3.03	10.13	1081	1123	1047	0.9
11	600	———	3.0	75	744	0.1	0.0	19.7	6000	225	2.35	9.93	89	70	65	1.7
12	2100	70.9	34.7	76	1301	4.8	0.4	3.2	1950	76	2.21	11.15	1981	1877	1834	0.8
13	2100	62.0	31.5	79	1259	3.8	0.3	6.0	2100	76	2.93	10.48	[illegible]97	1397	1397	0.7
14	2100	53.0	27.5	74	1199	2.9	0.2	8.7	2300	75	3.15	10.09	[illegible]03	1311	1280	7
15	2100	44.1	24.4	77	1164	2.2	0.2	10.9	2700	85	3.69	10.07	1461	1310	1278	0.7
16	2100	35.2	21.9	73	1106	1.7	0.2	13.4	2900	95	4.01	10.04	1266	1177	1145	0.7
17	2100	26.8	19.3	72	1053	1.3	0.1	14.8	3100	114	4.36	9.64	1071	984	963	0.7
18	2100	17.8	14.8	72	973	0.8	0.1	16.9	3550	135	4.79	9.35	684	620	459	0.7
19	2100	8.9	12.1	71	899	0.6	0.0	18.5	6900	156	4.69	9.28	440	394	386	0.9
20	2100	———	9.0	71	871	0.3	0.0	20.0	7000	244	5.17	8.41	132	105	96	1.7
21	662	———	3.4	71	688	0.1	0.0	19.6	8400	408	2.70	9.46	89	59	56	2.3
22	1450	———	3.4	82	438	0.0	0.0	21.4	38,500	2630	2.56	5.70	93	10.9	7.2	7.8
23	2150	———	3.0	74	401	0.0	0.0	21.4	28,500	4040	1.94	3.84	71	8.2	4.7	10.2

ENGINE FORD G5000 DATE 3/29/72 WET BULB TEMP., °F 62

RUN 2 BAROMETER, in Hg 29.04 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	655	———	3.2	70	788	0.1	0.0	19.7	9000	236	2.16	10.40	89	78	70	2.7
2	1400	———	7.1	70	632	0.2	0.0	19.8	12,700	450	6.71	7.80	87	55	49	1.7
3	1400	6.6	9.0	70	722	0.3	0.0	18.3	4950	310	5.55	9.20	221	191	173	1.0
4	1400	14.0	11.7	71	831	0.4	0.0	16.5	4300	197	4.89	9.68	437	383	383	1.1
5	1400	20.0	14.0	71	891	0.7	0.0	14.0	4000	165	4.66	9.79	563	528	511	1.1
6	1400	27.0	17.4	73	963	1.0	0.0	12.2	3550	155	4.40	10.00	696	751	648	1.1
7	1400	33.2	19.2	74	1045	1.4	0.1	10.2	2950	135	3.94	10.39	862	789	757	1.1
8	1400	39.9	21.5	73	1109	1.7	0.1	7.7	2850	115	3.39	10.64	1132	1060	1037	1.1
9	1400	46.6	24.2	75	1172	1.9	0.1	5.1	2700	105	2.84	11.07	1308	1285	1210	1.0
10	1400	52.8	26.8	76	1194	2.7	0.2	2.4	2650	95	3.25	10.94	980	1069	940	0.9
11	655	———	3.1	75	836	0.1	0.0	19.9	8950	316	2.15	10.50	89	68	64	2.3
12	2100	71.4	33.9	76	1273	4.6	0.4	3.2	2200	96	2.17	11.33	2035	1905	1851	0.7
13	2100	62.0	32.4	78	1259	3.9	0.3	5.9	2150	76	3.01	10.93	1407	1450	1407	0.6
14	2100	53.0	28.1	78	1197	2.8	0.3	8.9	2300	75	3.30	10.65	1475	1371	1339	0.6
15	2100	44.1	25.2	80	1167	2.3	0.2	11.1	2650	75	3.57	10.43	1423	1317	1251	0.6
16	2100	35.2	22.4	78	1117	1.8	0.2	12.9	2850	95	3.95	10.22	1257	1154	1111	0.6
17	2100	26.8	18.7	78	1032	1.2	0.1	15.0	3300	114	4.45	9.99	992	895	852	0.7
18	2100	17.8	15.6	78	981	0.9	0.1	16.9	3500	114	4.68	9.62	779	640	630	0.7
19	2100	8.9	12.4	78	918	0.6	0.0	18.2	3700	135	4.90	9.51	475	426	384	0.8
20	2100	———	9.3	78	874	0.3	0.0	20.1	6500	290	5.16	8.65	143	115	110	1.6
21	655	———	3.2	77	690	0.1	0.0	20.1	9000	501	2.88	9.79	77	61	56	2.5
22	1450	———	3.4	82	443	0.0	0.0	21.4	36,000	2440	2.47	6.05	69	10.0	6.8	7.8
23	2150	———	3.4	74	409	0.0	0.0	21.6	34,500	5830	2.12	3.83	71	8.5	5.0	9.7

ENGINE FORD G5000 DATE 3/30/72 WET BULB TEMP., °F 63

RUN 3 BAROMETER, in Hg 28.99 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	EXHAUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	700	———	3.2	63	496	0.1	0.0	19.3	8400	227	1.91	9.27	101	62	55	3.6
2	1400	———	6.9	63	622	0.2	0.0	19.5	12,600	523	6.77	7.22	87	48	41	2.3
3	1400	6.6	8.7	63	733	0.3	0.0	18.1	5000	336	5.52	8.54	223	173	164	1.3
4	1400	14.0	11.1	64	798	0.4	0.0	16.3	4400	210	4.93	8.91	440	360	343	1.5
5	1400	20.0	13.5	65	870	0.7	0.0	14.3	4000	178	4.71	8.94	581	499	473	1.4
6	1400	27.0	16.6	66	941	0.9	0.0	11.9	3700	136	4.44	9.14	716	629	603	1.2
7	1400	33.2	18.9	67	1005	1.3	0.0	9.9	3000	137	3.90	9.36	874	708	700	1.3
8	1400	39.9	20.7	68	1086	1.6	0.1	7.5	2850	106	3.52	9.56	991	930	908	1.2
9	1400	46.6	23.8	68	1155	1.8	0.1	5.1	2550	96	3.08	9.96	1306	1136	1125	1.1
10	1400	53.9	27.2	70	1214	2.8	0.3	2.2	2500	76	3.24	10.12	1080	1014	971	0.9
11	685	———	3.1	70	822	0.1	0.0	19.8	8600	182	2.33	9.14	90	63	60	2.2
12	2100	72.4	35.3	70	1246	4.8	0.5	3.1	2200	76	2.00	11.36	1981	1877	1845	0.9
13	2100	62.0	31.2	74	1254	3.7	0.4	6.2	2300	65	2.97	10.68	1549	1397	1376	0.8
14	2100	53.0	27.4	76	1201	2.8	0.3	9.0	2550	76	3.19	10.48	1497	1386	1333	0.8
15	2100	44.1	24.8	75	1158	2.3	0.2	11.4	2800	85	3.62	10.35	1424	1285	1285	0.8
16	2100	35.2	22.1	75	1109	1.8	0.2	12.9	3000	104	4.10	10.03	1257	1144	1047	0.8
17	2100	26.8	18.3	75	1036	1.2	0.1	15.0	3200	114	4.41	9.82	1038	897	854	0.8
18	2100	17.8	15.5	75	982	0.9	0.1	16.7	3600	146	4.75	9.36	726	642	621	0.8
19	2100	8.9	12.9	77	916	0.6	0.0	18.6	3700	155	5.02	9.25	365	384	331	1.0
20	2100	———	9.0	78	871	0.3	0.0	20.0	6000	244	5.06	8.51	132	103	96	1.7
21	690	———	2.0	79	720	0.1	0.0	20.0	7500	368	2.61	9.99	89	60	54	2.5
22	1450	———	3.2	81	433	0.0	0.0	21.4	29,000	2920	2.48	5.85	93	10.0	7.1	7.7
23	2150	———	3.5	74	417	0.0	0.0	21.7	41,000	4190	2.08	4.01	71	8.8	5.1	9.2

ENGINE FORD G5000 DATE [illegible] WET BULB TEMP, °F 63

RUN 1 BAROMETER, in Hg 29.22 DRY BULB TEMP °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	700	———	3.1	73	325	0.1	0.0	20.2	7200	561	2.37	10.01	89	64	57	2.9
2	1400	———	6.9	72	704	0.2	0.0	19.8	14,400	769	6.89	7.50	76	52	43	2.0
3	1400	6.6	8.4	72	792	0.2	0.1	18.5	4700	219	6.12	8.73	198	144	144	1.1
4	1400	13.3	10.6	73	865	0.4	0.1	16.3	4000	198	5.24	9.22	388	341	319	1.2
5	1400	20.0	13.7	72	925	0.7	0.1	14.5	3600	177	4.79	9.53	577	512	491	1.1
6	1400	26.6	15.6	72	986	0.8	0.2	12.4	3300	156	4.36	9.83	671	641	631	1.2
7	1400	33.2	17.7	74	1058	1.2	0.2	10.2	2800	125	3.81	10.23	923	803	770	1.1
8	1400	39.9	21.0	71	1132	1.6	0.3	7.6	2700	105	3.31	10.47	1167	1170	1031	1.0
9	1400	46.6	23.8	71	1197	2.2	0.4	5.0	2200	95	2.80	10.89	1410	1267	1246	0.9
10	1400	52.8	28.2	70	1179	2.9	0.4	2.6	2300	167	2.97	10.68	1232	1053	967	1.0
11	700	———	3.2	70	630	0.1	0.0	20.0	6800	225	2.31	9.75	100	70	65	2.6
12	2100	71.9	34.4	79	1294	4.7	0.6	3.6	2200	76	2.27	11.32	1935	1720	1720	0.7
13	2100	62.0	32.2	77	1232	3.7	0.4	6.8	2450	85	3.05	10.67	1565	1428	1353	0.7
14	2100	52.0	27.2	77	1175	2.9	0.3	9.2	2700	95	3.31	10.47	1495	1353	1245	0.7
15	2100	44.1	24.4	76	1128	1.8	0.2	11.4	3000	115	3.53	10.44	1391	1264	1253	0.8
16	2100	35.2	22.5	75	1062	1.7	0.2	13.4	3300	115	4.10	10.02	1193	1079	1058	0.8
17	2100	26.8	18.9	75	992	1.1	0.1	15.0	3750	135	4.46	9.82	892	854	854	0.8
18	2100	17.8	15.5	74	929	0.9	0.1	17.0	4050	145	4.84	9.51	723	597	580	0.8
19	2100	8.9	12.1	74	864	0.6	0.0	18.6	4300	199	4.75	9.27	426	368	355	0.9
20	2100	———	9.2	74	781	0.3	0.0	20.2	6700	314	5.23	8.57	132	96	90	2.0
21	695	———	3.2	74	518	0.1	0.0	19.8	10,000	412	1.66	9.55	90	63	60	3.1
22	1450	———	3.3	82	427	0.0	0.0	21.4	34,000	2840	2.42	5.92	87	10.4	7.0	8.0
23	2150	———	3.3	74	410	[illegible]	0.0	21.5	33,600	4180	2.06	3.92	59	7.6	4.9	9.8

ENGINE FORD G5000 DATE 3/31/72 WET BULB TEMP., °F 64

RUN 5 BAROMETER, in Hg 29.18 DRY BULB TEMP., °F 73

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	650	———	3.2	74	599	0.0	0.0	20.2	6900	225	2.16	9.82	89	68	63	3.0
2	1600	———	7.3	76	555	0.0	0.0	20.5	8400	247	6.36	9.43	89	54	53	3.0
3	1600	14.4	12.8	76	780	0.2	0.0	17.0	4600	198	5.31	8.69	351	281	273	1.4
4	1600	31.6	16.3	77	967	0.6	0.1	12.3	3650	177	4.41	9.45	752	641	624	1.1
5	1600	45.6	20.9	78	1119	1.2	0.4	7.8	2900	135	3.49	10.15	1072	975	921	1.0
6	1600	60.4	27.5	79	1188	2.0	0.5	3.2	2700	105	3.31	10.25	1072	964	953	0.9
7	650	———	3.3	78	890	0.0	0.0	20.2	7100	158	2.48	10.05	111	86	76	1.8
8	1900	67.9	35.4	84	1264	3.5	0.7	3.7	2500	115	3.05	10.46	1425	987	722	0.8
9	1900	52.2	25.9	82	1184	2.3	0.5	8.3	2800	95	3.48	10.24	1291	856	813	0.8
10	1900	34.2	18.3	81	1005	1.0	0.2	13.3	3500	95	4.35	9.61	778	789	746	0.8
11	1900	16.6	10.5	73	933	0.5	0.1	15.7	4150	135	5.68	8.57	256	200	178	1.8
12	1900	———	5.4	74	681	0.0	0.0	19.4	5250	156	4.92	8.89	98	56	53	2.0
13	650	———	3.3	74	562	0.0	0.0	19.5	7400	293	2.80	9.40	88	52	49	3.0

ENGINE FORD G5000 DATE 3/31/72 WET BULB TEMP., °F 68

MAPPING RUN M-1 BAROMETER, in Hg 29.08 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP, °F INTAKE AIR	TEMP, °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	650	—	3.2	74	517	0.0	0.0	19.5	8100	293	1.85	9.84	89	54	51	3.0
2	1600	—	7.7	74	704	0.1	0.0	19.4	14,000	491	6.36	7.90	98	52	47	1.8
3	1600	14.8	12.5	76	860	0.4	0.0	16.1	4400	286	5.41	9.09	386	314	297	1.0
4	1600	30.4	19.1	76	1009	0.9	0.2	11.8	3650	186	4.77	9.58	667	627	595	1.0
5	1600	44.8	25.0	78	1156	1.9	0.4	6.5	2700	135	3.53	10.22	1010	962	951	0.9
6	1600	58.8	29.8	78	1225	2.4	0.6	2.3	2350	115	3.09	10.64	1071	1037	995	0.8
7	650	—	3.0	80	860	0.0	0.0	19.5	8600	329	2.48	9.97	100	54	51	1.9
8	1900	66.5	33.1	84	1248	4.3	0.8	2.4	2400	56	3.09	10.64	1356	1091	1070	0.7
9	1900	51.8	27.5	88	1191	3.8	0.7	7.8	2700	75	3.90	10.10	1098	1002	960	0.6
10	1900	34.2	19.9	88	1032	2.4	0.3	12.3	3400	103	4.76	9.85	857	668	636	0.6
11	1900	17.1	15.2	88	931	0.9	0.2	16.0	4000	124	5.36	9.02	511	415	361	0.6
12	1900	—	8.6	88	827	0.4	0.1	19.4	10,800	347	5.93	8.40	119	66	58	1.2
13	650	—	3.7	87	595	0.0	0.0	19.8	9600	501	4.76	9.13	100	44	40	1.7

ENGINE FORD G5000 DATE 3/31/72 WET BULB TEMP., °F 68

MAPPING RUN M-2 BAROMETER, in Hg 29.08 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXH-AUST	RESTRICTIONS INTAKE in H_2O	RESTRICTIONS EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	600	———	2.8	86	549	0.2	0.0	19.1	5900	168	5.27	8.09	39	34	29	2.5
2	1450	———	6.3	88	596	0.3	0.0	19.3	3500	73	3.29	10.67	79	72	70	1.1
3	1450	6.9	8.8	87	727	0.4	0.0	16.9	3900	98	4.52	10.15	145	136	132	0.8
4	1450	13.7	12.8	88	824	0.7	0.0	14.5	3800	88	4.94	9.50	259	255	238	0.8
5	1450	20.3	15.5	87	901	0.9	0.0	12.3	3750	108	5.03	9.25	325	324	303	0.9
6	1450	27.0	17.3	88	953	1.1	0.0	10.0	3600	118	4.90	9.34	392	406	394	0.8
7	1450	33.4	19.9	88	984	1.3	0.1	8.1	3500	107	4.69	9.96	446	467	446	0.8
8	1450	39.4	24.8	87	1061	1.8	0.1	6.2	3200	107	4.53	9.89	616	596	586	0.6
9	1450	45.8	26.5	87	1099	1.8	0.1	3.7	3050	98	4.66	9.53	544	790	747	0.8
10	1450	53.3	33.2	85	1109	0.0	0.1	1.7	2850	116	7.11	8.43	422	380	359	0.9
11	600	———	2.7	84	475	0.2	0.0	18.9	9600	321	6.59	6.80	19	25	18	3.1
12	2400	75.6	38.7	85	1226	1.3	0.1	2.3	1850	71	3.54	10.51	1084	1015	982	0.5
13	2400	64.8	35.6	88	1235	2.3	0.1	4.2	2050	80	4.13	10.46	891	914	892	0.4
14	2400	56.4	32.1	87	1188	2.4	0.1	6.2	2200	89	4.53	9.79	705	703	671	0.4
15	2400	45.6	27.3	87	1147	2.2	0.1	8.4	2200	98	4.59	9.79	666	607	575	0.6
16	2400	37.2	23.9	87	1130	1.8	0.1	10.4	2500	98	4.83	10.18	531	466	458	0.4
17	2400	27.1	22.0	89	1063	1.4	0.0	12.6	2450	98	4.83	10.20	531	469	459	0.4
18	2400	18.5	18.2	88	1009	1.2	0.0	14.3	2700	80	5.46	9.12	238	255	238	0.4
19	2400	9.0	14.2	86	946	0.8	0.0	16.4	2650	71	5.20	9.22	176	153	145	0.5
20	2400	———	10.0	86	913	0.6	0.0	18.7	2700	69	5.28	10.24	108	96	90	1.2
21	600	———	2.4	84	561	0.3	0.0	19.0	7000	276	5.76	7.28	39	30	24	2.7
22	1400	———	2.8	80	368	0.0	0.0	21.0	54,000	3538	2.62	3.85	52	8.3	1.8	10.6
23	2450	———	2.6	91	553	0.0	0.0	20.9	43,800	2196	0.94	2.82	42	7.4	3.1	12.9

ENGINE HERCULES G-2300 DATE 6/16/72 WET BULB TEMP., °F 70

RUN 2 BAROMETER, in Hg 29.05 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP, °F INTAKE AIR	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	600	———	3.2	81	426	0.0	0.0	18.6	5750	156	5.83	8.09	57	33	27	2.6
2	1450	———	5.9	81	672	0.0	0.0	18.9	3850	88	3.81	10.65	96	64	63	1.3
3	1450	6.9	9.5	81	735	0.0	0.0	16.6	4250	90	4.23	10.33	186	153	148	1.2
4	1450	13.9	12.5	81	822	0.5	0.0	14.4	4350	155	4.90	10.10	279	232	215	1.3
5	1450	20.3	16.6	82	891	1.0	0.0	12.3	4000	155	5.03	9.91	333	313	283	1.3
6	1450	27.0	19.1	82	959	1.2	0.0	9.9	3500	125	5.01	10.26	386	379	316	1.1
7	1450	34.1	21.4	83	997	1.5	0.0	7.5	3450	145	4.67	10.11	457	571	497	1.0
8	1450	40.6	22.5	85	1043	1.5	0.0	5.4	3050	99	4.63	10.48	512	523	494	1.2
9	1450	47.4	27.6	85	1106	1.6	0.0	3.2	3150	97	4.54	10.68	803	801	716	0.9
10	1450	54.0	33.8	86	1095	0.0	0.0	1.4	3350	105	6.54	9.24	341	356	314	0.8
11	600	———	3.0	85	550	0.0	0.0	18.4	7400	207	6.65	7.72	38	30	19	2.4
12	2400	76.2	39.5	84	1268	1.0	0.0	2.0	2300	61	3.47	10.88	1217	1126	1030	0.7
13	2400	66.0	37.5	86	1224	2.2	0.0	3.7	2700	70	4.11	10.53	1001	995	932	0.6
14	2400	56.4	33.2	87	1196	2.1	0.0	6.0	2800	80	4.39	10.41	832	794	740	0.6
15	2400	48.0	28.5	86	1158	2.0	0.0	8.2	3050	88	4.56	10.13	714	614	583	0.6
16	2400	37.8	24.2	88	1112	1.8	0.0	10.3	3150	97	4.66	10.28	549	516	464	0.6
17	2400	28.8	21.8	89	1067	1.5	0.0	12.0	3200	97	4.79	10.20	479	422	390	0.6
18	2400	19.2	16.8	90	1014	1.0	0.0	14.1	3400	52	5.03	10.09	279	249	228	0.7
19	2400	10.2	14.1	90	941	0.8	0.0	16.0	3600	70	5.17	9.54	185	161	152	0.7
20	2400	———	10.0	91	911	0.5	0.0	18.3	3000	52	4.76	9.40	105	85	81	1.2
21	600	———	3.3	89	635	0.0	0.0	18.8	7000	198	5.65	7.87	48	33	27	2.7
22	1400	———	3.3	80	405	0.0	0.0	20.9	53,600	3649	3.02	4.19	71	8.7	2.7	9.6
23	2450	———	2.6	92	443	0.0	0.0	20.9	37,200	2335	0.89	3.16	42	6.6	3.3	12.7

ENGINE HERCULES G-2300 DATE 6/19/72 WET BULB TEMP., °F 67

RUN 3 BAROMETER, in Hg 29.04 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE in H_2O	RESTRICTIONS EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	600	———	3.3	83	467	0.0	0.0	18.7	6400	129	5.68	7.26	48	34	29	2.9
2	1450	———	6.1	83	630	0.4	0.0	19.1	3400	71	3.10	10.18	97	76	72	1.2
3	1450	6.1	9.5	84	744	0.5	0.0	17.5	3550	89	3.69	10.12	187	154	150	1.2
4	1450	13.8	12.5	83	810	0.5	0.0	14.6	3950	118	4.72	9.07	359	321	303	1.2
5	1450	20.6	16.4	87	900	0.7	0.0	12.2	3700	127	5.01	9.03	460	409	349	1.2
6	1450	27.2	18.7	87	959	1.0	0.0	9.9	3500	118	4.83	9.14	426	437	405	1.2
7	1450	33.7	19.9	90	1003	1.5	0.0	7.5	3300	127	4.43	9.53	581	491	459	1.2
8	1450	40.6	21.8	89	1063	1.6	0.0	5.2	3000	71	4.47	9.60	705	544	511	1.0
9	1450	47.5	27.2	88	1087	1.6	0.0	3.3	2900	89	4.47	9.51	852	789	778	0.9
10	1450	53.6	34.4	91	1089	0.0	0.0	1.7	3100	88	6.22	8.53	422	465	391	0.7
11	600	———	3.2	89	527	0.0	0.0	18.7	8000	166	7.26	6.79	48	27	21	2.3
12	2400	74.7	38.8	95	1240	1.0	0.0	2.1	2350	81	3.91	9.22	1062	969	937	0.7
13	2400	66.6	37.5	93	1246	2.0	0.0	3.6	2300	71	4.39	9.02	1105	1052	955	0.6
14	2400	56.4	31.6	95	1176	2.3	0.0	6.4	2800	80	4.79	8.73	683	664	643	0.6
15	2400	48.0	29.0	99	1140	2.0	0.0	7.9	2950	80	5.34	8.69	519	490	437	0.6
16	2400	37.8	25.0	101	1112	1.7	0.0	10.3	3100	89	5.08	8.96	496	502	469	0.6
17	2400	28.2	22.2	100	1070	1.4	0.0	12.2	3100	89	4.97	8.63	474	460	428	0.7
18	2400	19.8	18.7	97	1013	1.1	0.0	14.1	3300	89	5.22	8.62	303	321	295	0.7
19	2400	10.2	14.1	96	965	0.7	0.0	16.3	3450	89	5.41	8.50	197	166	162	0.7
20	2400	———	10.0	96	918	0.5	0.0	18.5	3300	81	4.82	8.17	107	85	78	1.6
21	600	———	2.6	95	500	0.0	0.0	18.8	8400	44	5.72	6.54	265	30	24	3.2
22	1400	———	3.5	93	420	0.0	0.0	20.9	48,800	2733	3.27	4.74	81	12	4.5	9.5
23	2450	———	2.5	87	755	0.0	0.0	21.0	46,400	2179	0.87	2.98	42	7.6	2.8	12.7

ENGINE HERCULES G-2300 DATE 6/19/72 WET BULB TEMP., °F 68

RUN 4 BAROMETER, in Hg 29.03 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER bhp	FUEL FLOW lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE in H_2O	RESTRICTIONS EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	600	———	3.0	78	435	0.0	0.0	18.7	7300	165	6.48	7.87	57	34	27	2.0
2	1450	———	6.3	78	622	0.4	0.0	18.9	4000	97	3.23	11.15	96	68	66	1.2
3	1450	6.9	9.5	80	760	0.4	0.0	16.4	4300	115	4.42	10.57	184	160	147	1.0
4	1450	13.8	12.5	80	821	0.5	0.0	14.6	4000	134	4.82	10.44	277	252	235	1.2
5	1450	20.7	16.1	81	921	0.7	0.0	12.2	4050	144	4.95	10.15	331	353	302	1.2
6	1450	27.2	19.7	81	968	1.0	0.0	9.9	3750	153	4.64	10.44	431	514	483	1.1
7	1450	33.9	22.1	81	1021	1.4	0.0	7.9	3950	143	4.76	10.54	476	441	410	0.9
8	1450	41.0	25.2	83	1081	1.7	0.0	5.1	3450	144	4.40	11.04	618	587	545	0.8
9	1450	47.1	27.2	82	1120	1.7	0.0	3.4	3400	106	4.59	10.45	709	673	652	0.8
10	1450	54.0	31.8	83	1104	0.0	0.0	1.7	3700	115	6.75	9.38	328	323	270	0.8
11	600	———	3.1	82	538	0.0	0.0	18.6	8100	237	6.78	8.01	37	30	22	2.4
12	2400	75.6	40.2	82	1275	1.0	0.0	2.1	2700	52	3.27	10.33	1193	1069	1058	0.8
13	2400	66.0	36.8	87	1242	2.1	0.0	3.5	3100	61	4.69	9.56	847	763	711	0.8
14	2400	57.0	32.7	90	1187	2.2	0.0	5.5	3100	79	4.69	9.65	740	657	615	0.7
15	2400	47.4	30.4	92	1144	2.0	0.0	7.6	3400	87	5.08	10.06	500	462	420	0.7
16	2400	37.8	26.7	93	1110	1.8	0.0	9.8	3150	97	4.80	9.54	564	518	498	0.8
17	2400	28.2	21.8	90	1072	1.5	0.0	12.1	3300	107	4.98	9.53	434	381	359	0.8
18	2400	19.2	17.9	88	1013	1.0	0.0	14.3	3500	106	5.10	9.52	279	249	237	0.8
19	2400	9.6	14.7	88	949	0.7	0.0	16.1	3700	106	5.40	9.49	154	139	135	0.8
20	2400	———	10.0	89	892	0.5	0.0	18.4	3600	61	4.94	9.11	86	77	72	1.4
21	600	———	2.7	88	630	0.0	0.0	18.7	8400	208	5.73	7.62	38	33	26	2.9
22	1400	———	3.6	92	420	0.0	0.0	20.9	51,200	3065	3.33	4.30	82	12	4.5	9.5
23	2450	———	2.8	85	528	0.0	0.0	20.9	48,000	2074	1.05	2.32	43	8.1	3.3	13.2

ENGINE HERCULES G-2300 DATE 6/20/72 WET BULB TEMP., °F 70

RUN 5 BAROMETER, in Hg 29.03 DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP, °F INTAKE AIR	TEMP, °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	600	———	3.2	82	416	0.0	0.0	19.0	5200	129	5.79	6.54	58	34	27	3.1
2	1750	———	7.9	83	652	0.5	0.0	19.0	3200	90	3.03	9.56	128	99	91	1.5
3	1750	15.8	14.3	84	817	0.7	0.0	14.7	3550	118	5.09	8.71	315	274	265	0.9
4	1750	31.9	20.5	85	970	1.2	0.0	10.3	3200	127	4.79	9.07	593	556	534	0.9
5	1750	47.7	26.9	86	1058	2.0	0.0	5.9	2800	127	4.72	9.15	733	662	598	0.8
6	1750	63.0	35.5	87	1134	1.0	0.0	2.0	2300	107	5.72	8.99	625	603	508	0.6
7	600	———	3.3	90	590	0.0	0.0	18.8	6900	177	7.31	6.23	48	26	21	2.2
8	2100	71.9	36.8	91	1190	1.1	0.0	2.1	2200	98	4.97	8.80	721	641	609	0.6
9	2100	53.6	31.0	91	1143	2.2	0.0	5.9	2550	108	4.74	8.91	748	771	728	0.7
10	2100	35.7	24.1	91	1096	1.6	0.0	10.5	2850	62	4.86	8.73	595	578	557	0.8
11	2100	17.8	15.5	91	969	0.8	0.0	15.0	3150	80	5.24	8.38	326	270	253	0.7
12	2100	———	8.7	89	862	0.4	0.0	18.8	3200	90	4.16	8.31	98	76	71	1.9
13	600	———	3.0	89	459	0.0	0.0	18.9	6000	150	5.48	6.13	49	31	23	3.7

ENGINE HERCULES G-2300　　DATE 6/20/72　　WET BULB TEMP., °F 68

MAPPING RUN M-1　　BAROMETER, in Hg 29.03　　DRY BULB TEMP., °F 75

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	600	———	3.4	92	450	0.0	0.0	18.7	6000	99	6.75	6.35	58	35	28	2.4
2	1750	———	7.3	92	651	0.4	0.0	19.1	3150	109	3.14	9.06	119	86	83	1.3
3	1750	15.8	14.1	90	835	0.6	0.0	14.7	3900	198	5.37	8.46	304	270	244	0.9
4	1750	31.5	21.4	91	974	1.4	0.0	10.3	3300	178	5.11	8.48	535	537	526	0.8
5	1750	47.2	26.1	90	1074	1.9	0.0	6.1	2800	167	4.81	8.75	750	709	677	0.6
6	1750	63.0	35.5	91	1119	0.5	0.0	2.1	2500	147	6.20	8.08	484	490	437	0.5
7	600	———	2.6	93	653	0.0	0.0	18.8	7300	288	6.53	6.22	38	26	21	3.2
8	2100	70.9	38.2	97	1187	1.0	0.0	2.2	2500	128	5.31	8.47	633	611	558	0.8
9	2100	53.6	30.5	99	1142	2.1	0.0	5.9	2800	108	4.98	8.74	723	686	633	0.6
10	2100	35.7	23.7	97	1080	1.6	0.0	10.3	2950	128	4.81	8.75	634	601	580	0.6
11	2100	18.4	16.7	94	966	0.9	0.0	14.7	3200	137	5.23	8.64	349	308	304	0.6
12	2100	———	8.5	92	873	0.4	0.0	19.0	3200	72	4.14	8.89	98	64	79	1.4
13	600	———	3.1	91	472	0.0	0.0	19.1	6450	189	5.98	6.97	48	34	27	2.9

ENGINE HERCULES G-2300 DATE 6/20/72 WET BULB TEMP., °F 65

MAPPING RUN M-2 BAROMETER, in Hg 29.03 DRY BULB TEMP., °F 75

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	EXHAUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	350	—	2.7	67	315	0.8	0	16.6	7250	196	5.50	10.79	46	78	75	—
2	1400	—	7.7	69	665	2.9	0.1	17.0	5560	273	7.77	8 24	46	78	75	—
3	1400	4.2	8.1	74	729	3.2	0.1	16.5	5400	273	7.95	8.24	93	54	54	—
4	1400	8.2	9.5	82	802	4.4	0.2	14.8	4900	286	7.60	8 41	147	85	84	—
5	1400	12.6	11.4	86	848	5.7	0.3	12.6	4850	310	7.30	8.62	189	113	113	—
6	1400	16.1	12.5	86	892	6.3	0.4	11.2	4700	310	6.99	8.81	224	138	134	—
7	1400	20.3	13.8	88	965	8.5	0.5	9.4	4150	298	6.27	9.37	371	254	250	—
8	1400	24.5	15.7	89	998	10.7	0.6	7.1	3900	287	6.13	9.57	349	263	263	—
9	1400	28.2	16.3	89	1028	12.1	0.8	4.7	3850	287	5.80	9.76	470	365	361	—
10	1400	32.7	18.2	91	1067	16.4	1.0	2.4	3350	264	5.61	9.97	424	349	349	—
11	470	—	2.6	91	761	1.2	0	18.6	—	—	—	—	—	—	—	—
12	2100	42.0	24.1	88	1181	23.9	1.5	5.5	3200	144	5.60	10.14	580	—	—	—
13	2100	36.8	23.0	88	1168	21.9	1.2	6.5	3300	166	5.86	9.84	425	—	—	—
14	2100	31.2	19.7	91	1105	16.3	0.8	8.9	3500	197	6.33	9.37	326	—	—	—
15	2100	26.2	16.7	92	1066	13.4	0.6	11.3	3700	207	6.55	9.27	340	—	—	—
16	2100	21.3	15.8	92	1038	10.4	0.5	12.1	3800	230	6.55	9.28	319	—	—	—
17	2100	15.8	13.2	96	991	8.2	0.3	14.2	3800	241	6.92	8.91	239	—	—	—
18	2100	10.2	12.3	96	968	6.7	0.2	15.1	3850	228	7.58	9.19	160	—	—	—
19	2100	5.0	11.3	95	953	6.1	0.1	15.9	3850	228	7.58	9.00	160	—	—	—
20	2100	—	10.8	96	944	5.8	0.1	16.3	3900	219	7.56	8.21	169	—	—	—
21	500	—	2.4	97	756	1.4	0	18.9	5550	289	7.06	8.02	170	—	—	—
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

ENGINE J.I. CASE 159 G DATE 2/9/72 WET BULB TEMP., °F 55

RUN 2 BAROMETER, in Hg 29.46 DRY BULB TEMP., °F 75

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	470	———	2.6	84	722	1.4	0	17.9	4900	243	7.22	7.21	87	44	42	1.6
2	1400	———	6.1	82	667	2.2	0	17.4	5900	242	8.13	6.71	73	67	64	1.5
3	1400	4.2	7.0	82	694	3.1	0.1	16.3	5350	241	7.93	7.08	100	77	74	1.2
4	1400	8.2	9.2	80	786	4.5	0.1	14.5	4200	219	7.41	7.87	132	123	119	1.0
5	1400	12.2	10.3	82	825	5.6	0.1	12.8	3900	197	7.00	7.95	189	165	162	1.0
6	1400	16.4	11.6	83	890	6.8	0.2	10.6	3650	197	6.78	8.30	246	178	178	0.9
7	1400	20.3	12.9	82	933	8.1	0.2	9.1	3450	191	7.51	10.24	367	383	379	0.9
8	1400	24.5	14.7	83	985	9.9	0.4	6.8	3200	191	7.28	10.53	396	380	359	0.9
9	1400	28.4	16.3	87	1024	12.7	0.5	4.1	3100	171	6.97	10.57	581	644	636	0.9
10	1400	32.4	17.7	88	1047	14.8	0.7	2.2	2900	179	5.83	7.44	455	458	450	0.8
11	490	———	2.6	90	692	1.3	0.1	18.5	4800	125	7.37	7.26	53	45	40	1.9
12	2100	41.7	22.9	84	1136	23.1	1.5	5.6	2550	134	5.49	9.13	631	639	621	0.6
13	2100	36.8	21.6	87	1141	19.2	1.2	7.1	2600	114	5.88	8.95	425	486	486	0.7
14	2100	31.5	18.8	88	1113	16.3	1.0	8.9	2700	135	6.03	8.76	409	383	375	0.8
15	2100	26.2	17.2	89	1088	12.6	0.8	10.5	2850	155	6.15	8.68	350	345	341	0.8
16	2100	21.0	14.8	91	1045	10.2	0.6	12.2	2850	124	6.22	8.67	387	374	366	0.8
17	2100	15.8	13.0	91	1014	8.8	0.4	13.6	2800	145	6.36	8.50	313	315	302	0.8
18	2100	10.5	11.7	89	983	6.8	0.3	14.9	2850	133	6.78	8.30	183	170	166	0.8
19	2100	5.2	11.1	86	958	5.9	0.2	15.7	2950	124	7.32	7.87	134	103	101	0.8
20	2100	———	10.4	85	947	5.6	0.2	16.2	2950	114	7.33	7.79	121	93	93	0.9
21	510	———	2.4	88	741	1.4	0	18.9	4500	199	6.70	7.39	67	45	41	2.2
22	1385	———	2.9	79	421	0.5	0	20.6	54,400	3346	3.48	4.25	36	13	5	9.6
23	2060	———	3.1	85	354	0.5	0	20.7	75,200	6480	1.75	2.47	66	8	3	13.7

ENGINE J. I. CASE 159 G DATE 2/10/72 WET BULB TEMP., °F 59

RUN 3 BAROMETER, in Hg 29.35 DRY BULB TEMP., °F 71

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	490	———	2.6	79	570	1.4	0.1	18.7	5000	85	6.65	7.48	67	45	43	2.4
2	1400	———	6.3	78	638	2.3	0.1	17.9	6100	186	8.01	7.39	93	64	60	1.5
3	1400	4.0	7.5	84	737	3.9	0.1	16.7	5600	164	7.72	7.77	120	93	89	1.1
4	1400	8.0	8.9	86	780	4.4	0.2	15.1	4550	103	7.32	8.12	155	138	134	0.9
5	1400	12.2	10.2	82	832	5.4	0.2	13.6	4400	154	7.08	8.29	197	170	168	1.5
6	1400	16.1	11.4	84	883	6.3	0.3	11.8	4200	164	6.85	8.56	211	216	208	0.9
7	1400	20.5	13.4	86	937	8.7	0.4	9.1	3750	165	6.08	9.04	226	400	392	0.9
8	1400	24.7	14.6	85	1001	10.2	0.5	7.0	3500	134	5.88	9.22	425	408	404	1.1
9	1400	28.4	16.3	88	1025	12.3	0.6	4.8	3400	155	5.50	9.42	616	704	704	1.1
10	1400	32.4	18.0	85	1057	17.5	0.8	2.5	3100	135	5.43	9.51	552	511	511	0.8
11	510	———	2.7	87	742	1.5	0	19.1	5100	155	7.21	7.59	40	50	43	1.8
12	2100	41.8	23.3	90	1143	23.2	1.5	5.5	2900	155	5.61	9.58	549	701	701	0.8
13	2100	36.8	21.7	92	1155	19.9	1.2	7.5	3050	93	6.13	9.19	424	509	509	0.7
14	2100	31.5	19.5	91	1133	16.7	1.0	8.8	3150	115	6.19	9.10	413	407	407	0.7
15	2100	26.2	17.7	90	1094	13.5	0.8	10.4	3250	134	6.34	9.01	363	371	361	0.8
16	2100	21.0	16.1	88	1057	10.8	0.6	12.1	3200	114	6.34	9.01	239	403	382	0.8
17	2100	16.0	14.2	87	1024	9.3	0.4	13.3	3200	134	6.27	9.01	401	403	403	0.8
18	2100	10.8	12.1	85	1000	7.2	0.3	15.3	3200	125	6.83	8.80	205	197	188	0.8
19	2100	4.7	11.2	87	961	5.8	0.2	16.3	2350	104	7.46	8.28	114	109	105	0.8
20	2100	———	10.7	88	949	5.6	0.2	16.5	3300	104	6.73	8.25	114	107	106	0.9
21	490	———	2.8	90	781	1.3	0	19.1	4950	176	7.50	7.79	47	53	47	2.0
22	1400	———	2.9	86	404	0.5	0	20.5	52,800	3875	3.70	4.31	49	9	5	9.6
23	2080	———	3.2	95	426	0.5	0	20.9	84,000	8340	1.63	1.90	120	8	3	13.9

ENGINE J. I. CASE 159 G DATE 2/11/72 WET BULB TEMP., °F 58

RUN 4 BAROMETER, in Hg 29.29 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	EXHAUST	RESTRICTIONS INTAKE, in H_2O	EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	480	———	2.8	90	604	1.2	0	17.6	6500	201	6.91	6.97	67	48	43	2.4
2	1400	———	5.7	90	644	2.2	0	18.0	10,200	198	8.99	6.06	46	38	28	1.8
3	1400	4.2	6.4	89	648	2.4	0.1	17.3	8200	209	9.07	6.26	66	46	39	1.3
4	1400	8.2	8.7	89	776	4.3	0.1	14.5	5900	197	8.73	6.99	107	83	81	1.0
5	1400	12.2	9.6	92	820	5.6	0.2	12.8	5700	218	8.37	7.15	127	104	100	1.0
6	1400	16.1	11.9	91	884	7.5	0.3	10.6	5500	219	8.04	7.34	149	132	128	0.9
7	1400	20.5	13.9	95	936	8.9	0.4	8.4	4950	242	7.35	7.91	240	200	196	1.0
8	1400	24.5	15.6	93	983	10.8	0.5	6.1	4650	198	7.05	8.01	270	248	247	1.1
9	1400	28.4	17.5	96	1021	13.5	0.7	3.8	4200	199	6.33	8.54	521	462	462	1.0
10	1400	31.8	17.9	95	1037	16.3	0.8	2.3	4050	187	6.44	8.52	351	320	307	0.9
11	510	———	2.2	97	861	1.3	0.1	18.6	6200	200	7.26	7.16	60	50	44	2.0
12	2100	42.0	24.0	91	1145	24.8	1.6	4.0	2200	115	5.64	9.17	625	556	556	0.8
13	2100	36.8	22.8	95	1164	17.9	1.4	5.8	2300	115	6.03	8.89	419	470	449	0.6
14	2100	31.5	19.8	99	1113	13.3	1.1	8.3	2550	145	6.82	8.18	307	290	286	0.7
15	2100	26.2	17.5	95	1092	11.3	0.9	10.0	4200	198	6.98	8.10	307	265	248	0.8
16	2100	21.3	16.2	98	1052	9.6	0.6	11.4	4200	188	7.00	7.95	322	291	279	0.8
17	2100	15.8	13.8	96	1012	7.6	0.4	13.3	4250	166	7.29	7.75	255	231	231	0.8
18	2100	10.8	11.7	98	959	5.7	0.2	14.8	4800	176	8.37	7.15	107	85	85	0.9
19	2100	5.8	10.3	96	912	4.3	0.2	16.5	4600	145	8.47	7.00	94	77	72	0.9
20	2100	———	8.1	95	901	3.1	0.1	18.4	11,000	1268	7.22	6.58	109	87	81	1.5
21	500	———	2.2	95	722	1.3	0	20.1	6700	271	6.04	6.81	54	42	35	3.7
22	1405	———	3.1	80	337	0.4	0	20.6	52,800	3945	3.42	4.68	49	15	7	8.3
23	2080	———	3.1	92	422	0.4	0	21.2	87,200	6435	2.60	2.41	58	9	4	12.9

ENGINE J.I. CASE 159 G   DATE 2/15/72   WET BULB TEMP., °F 57

RUN 5   BAROMETER, in Hg 28.98   DRY BULB TEMP., °F 76

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppmC	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	510	———	2.6	87	43[illegible]	1.3	0	19.6	7000	180	6.09	6.63	54	40	36	3.5
2	1400	———	4.7	80	6[illegible]	1.9	0	19.2	9500	188	7.99	6.45	60	39	36	2.1
3	1400	4.0	6.5	79	681	2.6	0.1	17.4	6400	175	8.46	6.84	80	67	62	1.3
4	1400	8.0	7.8	84	771	3.9	0.1	15.6	5200	84	8.16	7.29	120	106	100	1.2
5	1400	12.1	10.3	81	832	5.4	0.2	13.5	4700	124	7.58	7.64	162	149	149	0.9
6	1400	16.3	11.6	85	8[illegible]5	6.3	0.3	11.3	4550	134	7.41	7.87	190	185	174	0.8
7	1400	20.3	13.4	88	946	8.4	0.4	8.9	4100	135	6.51	8.50	328	341	323	0.9
8	1400	24.5	14.8	88	9[illegible]5	10.1	0.6	6.8	3800	133	6.09	8.51	247	350	337	0.9
9	1400	28.5	17.0	88	1041	13.0	0.8	4.3	3550	133	5.76	8.87	593	591	591	0.8
10	1400	31.8	17.9	85	1053	15.8	0.9	2.8	3450	124	5.94	9.03	456	458	458	0.7
11	520	———	2.4	88	841	1.4	0	19.9	6600	157	6.45	6.80	54	46	39	3.3
12	2100	39.1	24.0	82	1188	23.9	1.5	5.1	3150	95	5.95	8.87	591	575	562	0.8
13	2100	34.6	21.7	82	1146	18.1	1.2	6.5	3300	124	6.44	8.50	417	392	379	0.8
14	2100	28.9	19.3	81	1104	15.8	1.0	8.2	3450	134	6.80	8.24	313	290	285	0.9
15	2100	24.4	17.7	81	1069	12.1	0.8	9.9	3550	155	6.88	8.16	327	308	298	0.9
16	2100	20.0	15.2	81	1041	10.1	0.6	11.6	3650	155	6.79	8.40	349	340	319	0.8
17	2100	14.4	13.0	82	1002	8.0	0.4	13.4	3650	154	7.25	8.04	175	187	178	0.8
18	2100	10.2	12.1	85	950	6.3	0.2	14.6	3650	134	7.74	7.63	134	109	109	0.8
19	2100	5.0	9.8	88	926	5.0	0.1	16.5	4300	134	7.92	7.31	107	87	76	1.1
20	2100	———	7.2	87	871	2.9	0.1	18.2	14,800	783	7.10	6.10	109	78	69	3.6
21	500	———	2.5	86	663	1.4	0	19.7	6900	367	6.35	6.77	54	40	35	3.6
22	1400	———	3.0	81	368	0.4	0	20.5	55,200	4530	3.66	4.19	64	13	5	8.8
23	2085	———	2.9	94	414	0.4	0	21.2	85,600	7235	2.67	2.51	58	10	5	12.7

ENGINE J.I. CASE 159 G DATE 2/16/72 WET BULB TEMP., °F 59

RUN 6 BAROMETER, in Hg 29.19 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	625	———	3.0	89	452	0.5	0.0	19.3	6650	272	5.93	6.45	47	39	32	3.6
2	1600	———	6.3	89	660	1.5	0.0	18.7	8300	362	8.34	6.29	46	46	35	1.8
3	1600	8.4	9.7	90	805	5.0	0.3	15.6	5500	336	7.95	7.02	107	107	102	1.1
4	1600	16.8	13.0	93	898	6.6	0.4	11.6	4600	362	7.39	7.21	128	142	139	1.2
5	1600	24.8	16.3	92	987	10.8	0.6	7.8	4000	338	6.77	7.87	206	274	257	1.0
6	1600	33.6	23.5	98	1189	18.0	1.6	3.2	2700	327	4.95	9.14	508	681	560	0.4
7	620	———	2.9	95	603	0.5	0.0	19.3	6100	354	4.70	5.31	42	31	25	5.8
8	1900	39.9	24.0	92	1173	22.0	1.6	3.5	2550	339	4.83	9.32	477	788	775	0.4
9	1900	31.8	18.4	97	1103	17.5	1.1	6.3	3300	289	6.18	8.45	270	419	355	0.5
10	1900	22.3	15.2	99	1011	10.0	0.5	10.4	3400	313	6.75	8.01	248	312	299	0.6
11	1900	10.0	11.9	98	897	5.0	0.2	15.0	4000	134	7.84	7.40	94	106	97	0.8
12	1900	———	7.1	98	781	2.0	0.0	18.6	6000	198	8.05	6.88	60	60	51	1.3
13	700	———	2.7	100	518	0.5	0.0	19.5	7100	308	5.78	6.74	47	48	35	3.9

ENGINE J.I. CASE 159 G   DATE 3/17/72   WET BULB TEMP., °F 56

MAPPING RUN M-1   BAROMETER, in Hg 29.06   DRY BULB TEMP., °F 73

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	640	—	2.7	100	429	0.4	0.0	19.8	9000	324	3.33	8.05	48	52	49	4.0
2	1600	—	5.0	98	666	1.4	0.0	19.9	8000	427	7.58	6.91	67	31	29	2.1
3	1600	8.4	10.0	98	795	3.4	0.3	15.5	5400	299	8.18	7.31	80	98	90	1.7
4	1600	17.6	14.4	99	902	7.1	0.3	12.1	4250	264	7.59	7.49	135	171	153	0.8
5	1600	26.0	17.0	102	1011	13.2	0.6	7.2	3800	265	6.60	8.26	219	307	299	0.8
6	1600	33.6	21.3	106	1159	20.1	1.6	3.5	2900	222	4.49	9.79	—	796	752	0.6
7	800	—	3.0	106	761	0.4	0.0	19.5	6450	283	5.78	6.74	47	43	35	3.5
8	1900	39.4	22.7	105	1200	21.5	1.6	3.6	2900	233	4.24	9.72	581	841	798	0.5
9	1900	31.4	19.9	107	1090	16.2	0.9	7.0	5500	198	6.45	8.43	284	376	359	0.6
10	1900	21.8	16.6	107	1020	10.5	0.5	10.6	3800	165	6.89	8.17	219	311	303	0.7
11	1900	10.9	12.1	103	892	5.5	0.1	14.8	4400	186	8.18	7.38	100	101	98	0.8
12	1900	—	7.0	104	803	2.1	0.0	18.7	7000	219	8.57	6.70	59	50	41	1.1
13	760	—	2.8	104	525	0.4	0.0	19.8	6900	295	6.17	6.65	47	38	32	3.5

ENGINE J.I. CASE 159 G DATE 3/17/72 WET BULB TEMP., °F 56

MAPPING RUN M-2 BAROMETER, in Hg 29.06 DRY BULB TEMP., °F 73

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE in H_2O	RESTRICTIONS EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	890	—	3.1	73	690	0.0	0.0	—	14,500	—	9.45	6.22	23	27	19	0.39
2	1700	—	4.8	73	750	0.0	0.0	—	14,000	—	9.56	6.35	12	27	23	0.36
3	1700	2.8	5.7	73	795	0.0	0.0	—	9,780	—	8.49	7.24	29	52	48	0.36
4	1700	5.7	6.7	73	890	0.0	0.0	—	6,700	—	5.75	9.07	169	167	162	0.17
5	1700	8.5	8.5	73	950	0.7	0.0	—	6,430	—	5.96	8.87	256	238	238	0.17
6	1700	11.3	9.2	75	1010	0.9	0.0	—	6,320	—	5.88	9.06	327	295	295	0.17
7	1700	14.2	10.6	76	1085	1.0	0.0	—	5,900	—	5.77	8.71	398	356	356	0.19
8	1700	17.0	11.0	78	1110	1.3	0.0	—	5,220	—	5.24	9.21	608	583	583	0.15
9	1700	19.8	12.7	76	1200	1.9	0.0	—	4,200	—	4.60	9.55	1244	1205	1195	0.19
10	1700	22.7	14.6	77	1205	2.0	0.0	—	4,000	—	5.11	9.31	738	783	772	0.10
11	900	—	2.8	76	610	0.0	0.0	—	13,000	—	7.87	7.21	47	37	26	0.59
12	2800	32.7	21.1	77	1320	5.2	0.3	—	4,650	—	4.02	9.80	1228	1208	1205	0.32
13	2800	28.6	18.6	76	1360	4.5	0.3	—	4,050	—	3.86	10.01	1477	1469	1469	0.26
14	2800	24.5	17.8	76	1310	3.6	0.3	—	3,900	—	4.82	9.53	1043	988	988	0.18
15	2800	20.4	16.4	76	1260	2.7	0.2	—	4,040	—	5.31	9.11	824	780	780	0.16
16	2800	16.3	14.4	75	1210	2.2	0.1	—	4,820	—	5.70	8.90	538	536	536	0.09
17	2800	12.2	12.6	73	1050	1.6	0.0	—	6,000	—	5.91	8.51	342	292	292	0.37
18	2800	8.2	10.8	73	1040	1.2	0.0	—	6,500	—	6.19	8.41	248	204	196	0.33
19	2800	4.1	8.3	74	1000	0.7	0.0	—	6,500	—	6.11	8.59	157	121	121	0.26
20	2800	—	7.3	74	990	0.5	0.0	—	7,700	—	6.10	8.68	126	92	92	0.28
21	900	—	2.8	74	700	0.0	0.0	—	10,040	—	5.81	7.93	60	42	37	0.41
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

ENGINE WISCONSIN VH4D   DATE 11/24/72   WET BULB TEMP., °F 55

RUN 1   BAROMETER, in Hg 29.11   DRY BULB TEMP., °F 70

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	EXH-AUST	RESTRICTIONS INTAKE in H_2O	EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	925	—	2.4	76	640	0.1	0.0	—	6400	242	7.01	7.82	59	38	31	0.42
2	1700	—	5.4	76	780	0.2	0.0	—	4400	179	6.53	8.36	83	59	59	0.63
3	1700	2.8	5.5	78	830	0.3	0.0	—	3420	169	5.88	8.85	107	90	90	0.54
4	1700	5.7	6.5	78	890	0.4	0.0	—	2900	159	5.73	9.05	194	177	177	0.51
5	1700	8.5	7.8	78	940	0.7	0.0	—	2780	160	5.32	8.64	276	258	258	0.51
6	1700	11.3	9.4	79	1020	0.9	0.0	—	2750	159	6.16	8.66	313	307	307	0.40
7	1700	14.2	10.6	79	1080	1.1	0.1	—	2680	150	5.79	8.64	407	405	405	0.50
8	1700	17.0	11.4	79	1140	1.3	0.1	—	2420	138	5.54	9.06	574	572	572	0.43
9	1700	19.8	14.0	81	1210	2.0	0.2	—	1800	119	4.98	9.49	1206	1198	1198	0.66
10	1700	22.7	15.5	81	1250	2.8	0.2	—	1700	109	5.54	9.25	734	682	682	0.51
11	925	—	2.3	81	790	0.1	0.0	—	9400	321	7.25	7.72	41	43	35	1.1
12	2800	31.7	20.2	81	1370	5.1	0.4	—	1750	110	4.42	9.74	1221	1181	1171	0.69
13	2800	27.8	18.4	81	1350	4.2	0.4	—	1520	93	4.29	7.95	1408	1425	1403	0.69
14	2800	23.8	17.6	81	1300	3.3	0.3	—	2080	91	5.36	9.08	946	953	931	0.58
15	2800	19.8	16.7	81	1250	2.8	0.3	—	2510	91	5.64	9.01	705	709	709	0.53
16	2800	15.9	14.6	81	1200	2.1	0.2	—	3180	109	6.02	8.67	461	455	444	0.44
17	2800	11.0	12.6	81	1110	1.5	0.2	—	3260	129	6.30	8.46	299	290	281	0.43
18	2800	7.9	11.1	81	1050	1.2	0.2	—	4100	129	6.46	8.37	207	194	191	0.41
19	2800	4.0	8.9	81	1000	0.8	0.0	—	4200	129	6.46	8.27	131	122	119	0.67
20	2800	—	7.3	81	980	0.6	0.0	—	4800	169	6.03	8.40	95	90	86	0.76
21	950	—	2.5	81	700	0.1	0.0	—	8000	276	7.26	7.64	47	40	33	0.84
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

ENGINE WISCONSIN VH4D DATE 11/27/72 WET BULB TEMP., °F 60

RUN 2 BAROMETER, in Hg 28.90 DRY BULB TEMP., °F 74

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXH-AUST	RESTRICTIONS INTAKE in H_2O	RESTRICTIONS EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	900	——	2.4	75	650	0.2	0.0	——	7100	266	6.80	7.95	35	47	36	0.84
2	1700	——	4.2	75	720	0.3	0.0	——	7900	279	6.84	7.39	41	47	36	0.97
3	1700	2.8	5.2	75	800	0.4	0.0	——	4600	170	6.05	8.52	83	86	82	0.80
4	1700	5.7	6.0	76	870	0.5	0.0	——	3900	161	5.28	8.77	203	201	200	0.92
5	1700	8.5	7.7	76	930	0.7	0.0	——	4050	170	5.77	8.92	336	309	305	0.62
6	1700	11.3	9.1	76	1010	0.8	0.0	——	3560	110	6.19	8.71	356	343	341	0.71
7	1700	14.2	10.3	76	1070	1.1	0.1	——	3400	129	5.90	9.08	470	464	456	0.49
8	1700	17.0	11.3	76	1130	1.3	0.1	——	2960	129	5.50	9.21	608	618	618	0.45
9	1700	19.8	13.1	77	1200	1.8	0.2	——	2550	110	4.89	9.65	1192	1184	1179	0.36
10	1700	22.7	14.7	77	1250	3.0	0.2	——	2490	91	5.12	9.54	895	929	924	0.25
11	900	——	2.4	77	680	0.2	0.0	——	6300	210	6.95	8.12	47	51	43	0.62
12	2800	31.0	20.4	77	1380	5.4	0.6	——	2700	111	4.02	10.02	1367	1297	1276	0.20
13	2800	27.2	18.6	79	1350	4.0	0.4	——	2260	92	3.98	9.84	1519	1497	1497	0.49
14	2800	23.3	17.2	79	1300	3.3	0.4	——	2450	92	5.04	9.17	1068	1041	1031	0.28
15	2800	19.4	16.6	79	1260	2.7	0.3	——	2650	91	5.27	9.05	854	809	809	0.32
16	2800	15.4	14.0	79	1190	2.1	0.3	——	3320	130	5.79	8.74	503	497	484	0.20
17	2800	9.3	11.8	79	1080	1.3	0.2	——	4000	130	6.14	8.44	309	294	290	0.24
18	2800	7.9	9.7	79	1030	1.2	0.2	——	4110	139	6.21	8.44	215	214	213	0.28
19	2800	4.0	8.8	79	1000	0.8	0.1	——	4250	150	5.95	8.37	121	136	132	0.61
20	2800	——	6.9	79	990	0.6	0.0	——	5300	181	5.75	8.48	108	97	96	0.69
21	900	——	2.6	79	700	0.1	0.0	——	7600	278	6.98	7.62	41	43	38	0.59
22	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
23	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——

ENGINE WISCONSIN VH4D DATE 11/28/72 WET BULB TEMP., °F 52

RUN 3 BAROMETER, in Hg 29.46 DRY BULB TEMP., °F 70

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lbm/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE in H_2O	RESTRICTIONS EXHAUST in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR. O_2, %
1	900	—	2.7	76	590	0.2	0.0	—	11,100	367	8.30	7.50	29	31	26	0.18
2	1700	—	4.3	76	730	0.3	0.0	—	7,600	251	8.00	7.84	46	49	41	0.14
3	1700	2.8	5.6	76	790	0.4	0.0	—	4,950	189	6.59	8.92	76	83	79	0.14
4	1700	5.7	6.3	77	860	0.5	0.0	—	4,100	179	5.66	9.55	213	204	204	0.02
5	1700	8.5	8.2	78	940	0.7	0.0	—	4,220	179	6.08	9.14	279	302	294	0.04
6	1700	11.3	9.4	78	1020	0.9	0.1	—	4,180	169	6.01	9.01	340	351	341	0.14
7	1700	14.2	10.4	79	1090	1.1	0.1	—	3,950	158	5.87	9.35	453	453	353	0.17
8	1700	17.0	11.2	79	1140	1.3	0.2	—	3,180	158	5.60	9.66	627	618	618	0.10
9	1700	19.8	13.6	79	1210	1.8	0.2	—	2,650	138	4.86	10.02	1164	1170	1163	0.10
10	1700	22.7	15.0	79	1240	2.9	0.3	—	2,680	129	5.60	9.66	604	613	609	0.09
11	1000	—	2.6	79	760	0.2	0.0	—	6,600	240	7.12	8.60	40	52	42	0.08
12	2800	31.0	20.3	78	1370	5.3	0.5	—	2,620	202	4.23	9.59	1389	1352	1352	0.23
13	2800	27.3	18.7	78	1360	4.3	0.5	—	2,220	130	4.07	9.90	1512	1512	1490	0.15
14	2800	23.3	17.8	79	1310	3.4	0.4	—	2,440	130	5.24	9.41	1042	1030	1008	0.09
15	2800	19.4	16.1	79	1260	2.8	0.3	—	2,500	129	5.63	9.09	822	801	788	0.09
16	2800	15.4	13.3	79	1200	2.1	0.2	—	3,160	129	6.03	8.87	514	534	513	0.09
17	2800	9.3	11.5	79	1080	1.3	0.2	—	3,520	110	6.48	8.69	300	291	282	0.07
18	2800	7.9	10.8	79	1040	1.2	0.2	—	3,840	119	6.54	8.47	240	229	228	0.08
19	2800	4.0	8.7	79	1000	0.8	0.1	—	3,940	119	6.46	8.66	150	149	141	0.08
20	2800	—	7.6	79	990	0.6	0.1	—	5,000	149	6.10	8.77	95	99	95	0.14
21	1000	—	2.5	79	670	0.2	0.0	—	7,100	231	7.41	7.94	47	43	37	0.13
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

ENGINE WISCONSIN VH4D DATE 11/28/72 WET BULB TEMP., °F 54

RUN 4 BAROMETER, in Hg 29.44 DRY BULB TEMP., °F 72

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP., °F INTAKE AIR	TEMP., °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	1000	———	2.5	75	710	0.2	0.0	———	6300	276	6.93	8.10	29	49	39	0.83
2	2000	———	5.2	75	780	0.3	0.1	———	5700	189	6.84	8.36	47	65	60	0.59
3	2000	6.5	7.1	75	910	0.7	0.1	———	4150	169	5.81	9.16	240	252	248	0.63
4	2000	13.0	11.0	75	1060	1.2	0.1	———	3810	169	5.82	9.07	433	447	440	0.56
5	2000	19.5	13.5	75	1190	1.8	0.2	———	2960	159	5.10	9.71	946	931	916	0.43
6	2000	26.0	16.6	76	1280	3.2	0.3	———	2400	129	4.70	9.94	1090	1115	1115	0.34
7	1000	———	2.6	76	730	0.2	0.0	———	5500	254	6.63	8.12	29	49	41	0.50
8	2400	29.6	18.5	78	1340	4.3	0.4	———	2400	149	4.63	10.14	1247	1252	1205	0.36
9	2400	22.2	15.9	78	1280	2.7	0.2	———	2580	138	5.35	9.58	1038	1080	1076	0.37
10	2400	14.8	12.4	78	1150	1.6	0.2	———	3500	179	5.74	9.27	543	552	548	0.35
11	2400	7.4	9.3	75	950	0.8	0.1	———	4440	231	7.05	8.52	239	219	219	0.76
12	2400	———	5.4	75	880	0.3	0.1	———	5200	254	6.10	8.86	83	82	80	0.57
13	1000	———	2.6	75	650	0.2	0.0	———	7800	322	7.26	7.91	29	41	34	0.65

ENGINE WISCONSIN VH4D   DATE 11/29/72   WET BULB TEMP., °F 54

MAPPING RUN M-1   BAROMETER, in Hg 29.40   DRY BULB TEMP., °F 70

MODE	ENGINE SPEED, RPM	OBSERVED POWER, bhp	FUEL FLOW, lb_m/hr	TEMP, °F INTAKE AIR	TEMP, °F EXHAUST	RESTRICTIONS INTAKE, in H_2O	RESTRICTIONS EXHAUST, in Hg	MANIFOLD VACUUM, in Hg	FIA HC, ppm C	NDIR HC, ppm C_6	NDIR CO, %	NDIR CO_2, %	NDIR NO, ppm	C.L. NO_x, ppm	C.L. NO, ppm	POLAR O_2, %
1	900	———	2.6	74	570	0.2	0.0	———	10,600	299	7.98	7.22	29	37	27	0.49
2	2000	———	5.3	74	770	0.3	0.1	———	6,280	221	6.92	8.26	71	63	60	0.08
3	2000	6.5	7.5	75	910	0.6	0.1	———	4,290	180	5.90	8.88	247	244	235	0.07
4	2000	13.0	10.8	75	1050	1.2	0.1	———	3,580	159	5.83	8.98	448	439	435	0.09
5	2000	19.5	13.7	75	1210	1.9	0.2	———	2,680	147	6.25	9.59	925	943	926	0.02
6	2000	26.0	16.3	76	1270	3.1	0.3	———	2,190	129	4.75	9.93	1069	1048	1044	0.01
7	1000	———	2.7	76	730	0.2	0.0	———	12,800	321	6.85	8.27	47	51	41	0.08
8	2400	29.6	18.9	76	1340	4.3	0.4	———	2,480	150	4.48	10.08	1263	1200	1200	0.01
9	2400	22.2	15.9	77	1270	2.7	0.3	———	2,650	129	5.23	9.60	1126	1094	1081	0.03
10	2400	14.8	12.5	77	1160	1.6	0.2	———	3,460	169	5.75	9.17	574	557	551	0.03
11	2400	7.4	8.6	77	1000	0.8	0.1	———	3,750	179	6.31	8.76	233	233	231	0.03
12	2400	———	5.6	77	900	0.3	0.1	———	4,500	169	5.95	9.06	83	83	78	0.07
13	1000	———	2.5	77	710	0.2	0.0	———	7,400	300	6.49	8.14	35	41	36	0.09

ENGINE WISCONSIN VH4D

DATE 11/29/72

WET BULB TEMP., °F 56

MAPPING RUN M-2

BAROMETER, in Hg 29.36

DRY BULB TEMP., °F 72

APPENDIX G

COMPUTER-GENERATED DATA PRINTOUTS AND CALCULATION OF BRAKE SPECIFIC EMISSIONS FOR GASOLINE ENGINES USED IN FARM, CONSTRUCTION, AND INDUSTRIAL APPLICATIONS

FORD G5000 ENGINE NO E188653
23-MODE EMISSIONS TEST RUN 1 3/28/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	650	0.0	0	19.0	3.2	1452	-0	6900	1.962	9.75	73
2	1400	0.0	0	19.2	7.2	3248	-0	12000	6.572	7.56	61
3	1400	18.0	6	17.9	10.2	4622	-0	4600	5.460	9.09	247
4	1400	37.0	13	15.9	11.9	5393	-0	4200	5.465	9.01	346
5	1400	54.0	19	13.8	15.1	6854	-0	4300	5.217	9.20	444
6	1400	73.0	26	11.9	17.5	7915	-0	3500	4.637	9.77	650
7	1400	91.0	32	9.8	19.4	8809	-0	3350	4.421	9.97	834
8	1400	109.0	38	7.4	22.3	10106	-0	2900	3.872	10.38	998
9	1400	127.0	44	5.1	25.4	11503	-0	2250	3.186	10.82	1175
10	1400	151.0	53	2.1	28.6	12955	-0	2500	3.017	10.84	1177
11	650	0.0	0	19.3	3.1	1397	-0	6000	2.184	10.73	70
12	1400	0.0	0	21.4	3.3	1479	-0	32500	2.214	6.17	11
13	2100	134.0	70	3.1	37.7	17119	-0	2200	2.312	11.49	1963
14	2100	112.0	59	7.1	30.7	13935	-0	2300	3.101	10.83	1503
15	2100	96.0	50	9.0	28.5	12914	-0	2450	3.450	10.70	1391
16	2100	80.0	42	11.2	25.1	11385	-0	2950	3.907	10.56	1321
17	2100	64.0	34	13.1	20.4	9263	-0	3100	4.110	10.27	1149
18	2100	48.0	25	15.4	18.4	8364	-0	3350	4.629	9.95	865
19	2100	32.0	17	16.5	15.8	7149	-0	3600	4.848	9.83	702
20	2100	16.0	8	18.5	12.0	5452	-0	3250	4.977	9.56	346
21	2100	0.0	0	19.8	9.7	4404	-0	5000	5.119	8.87	131
22	650	0.0	0	19.7	3.2	1461	-0	7000	2.728	9.95	62
23	2100	0.0	0	21.3	3.3	1488	-0	30500	2.149	4.07	5

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	80.7	464	2.8	.067	0.0	0.0	5.38	30.9	.2
2	0.0	254.2	2812	4.3	.040	0.0	0.0	10.17	112.5	.2
3	0.0	141.6	3395	25.2	.040	.3	0.0	5.66	135.8	1.0
4	0.0	152.1	3498	41.7	.040	.5	0.0	6.08	159.9	1.7
5	0.0	198.6	4867	68.0	.040	.8	0.0	7.94	194.7	2.7
6	0.0	187.6	5025	115.8	.040	1.0	0.0	7.51	201.0	4.6
7	0.0	200.4	5342	165.6	.040	1.3	0.0	8.02	213.7	6.6
8	0.0	201.5	5434	230.3	.040	1.5	0.0	8.06	217.4	9.2
9	0.0	181.9	5202	315.4	.040	1.8	0.0	7.28	208.1	12.6
10	0.0	229.6	5597	358.9	.040	2.1	0.0	9.19	223.9	14.4
11	0.0	62.0	456	2.4	.067	0.0	0.0	4.14	30.4	.2
12	0.0	413.1	568	.5	.040	0.0	0.0	16.52	22.7	.0
13	0.0	266.6	5702	795.6	.040	2.8	0.0	10.74	228.1	31.8
14	0.0	226.3	6165	491.0	.040	2.4	0.0	9.05	246.6	19.6
15	0.0	219.8	6253	414.2	.040	2.0	0.0	8.79	250.1	16.6
16	0.0	227.5	6087	338.3	.040	1.7	0.0	9.10	243.5	13.5
17	0.0	195.5	5236	240.6	.040	1.3	0.0	7.82	209.4	9.6
18	0.0	187.9	5244	161.1	.040	1.0	0.0	7.52	209.8	6.4
19	0.0	171.1	4654	110.7	.040	.7	0.0	6.84	186.2	4.4
20	0.0	114.2	3687	42.2	.040	.3	0.0	4.77	147.5	1.7
21	0.0	152.0	3143	13.2	.040	0.0	0.0	6.08	125.7	.5
22	0.0	76.4	602	2.2	.067	0.0	0.0	5.10	40.1	.1
23	0.0	489.5	647	.3	.040	0.0	0.0	19.58	27.9	.0

CYCLE COMPOSITE			
	HC	8.916	GRAM/BHP HR
	CO	170.804	GRAM/BHP HR
	NO2	7.353	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.705	LB/BHP HR

FORD G5000 ENGINE NO E188653
23-MODE EMISSIONS TEST RUN 2 3/29/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	650	0.0	0	19.4	3.1	1424	-0	6550	2.573	9.96	71
2	1400	0.0	0	19.4	7.1	3216	-0	11100	6.427	7.65	59
3	1400	19.0	7	17.9	8.9	4042	-0	4850	5.537	8.76	192
4	1400	38.0	13	16.1	11.1	5035	-0	4400	5.119	8.87	353
5	1400	57.0	20	13.9	14.4	6541	-0	3900	4.778	9.07	510
6	1400	76.0	27	11.9	16.2	7366	-0	3700	4.562	9.25	597
7	1400	95.0	33	9.3	18.1	8210	-0	3150	4.093	9.47	765
8	1400	114.0	40	7.2	22.5	10197	-0	3000	3.657	9.86	973
9	1400	133.0	47	4.7	24.5	11122	-0	2600	3.119	10.28	1237
10	1400	151.0	53	2.0	27.1	12274	-0	2600	3.076	10.28	1139
11	650	0.0	0	19.7	3.0	1365	-0	6000	2.380	10.07	71
12	1400	0.0	0	21.4	3.3	1520	-0	38500	2.601	5.80	11
13	2100	134.0	70	3.2	34.7	15726	-0	1950	2.239	11.30	1903
14	2100	118.0	62	6.0	31.5	14279	-0	2100	2.974	10.84	1526
15	2100	101.0	53	8.7	27.5	12469	-0	2300	3.192	10.63	1417
16	2100	84.0	44	10.9	24.4	11045	-0	2700	3.736	10.22	1328
17	2100	67.0	35	13.4	21.9	9925	-0	2900	4.063	10.18	1194
18	2100	51.0	27	14.8	19.3	8750	-0	3100	4.429	9.79	999
19	2100	34.0	18	16.9	14.8	6695	-0	3550	4.865	9.49	629
20	2100	17.0	9	18.5	12.1	5484	-0	6900	4.762	9.41	400
21	2100	0.0	0	20.0	9.0	4069	-0	7000	5.252	8.53	106
22	650	0.0	0	19.8	3.4	1551	-0	8400	2.738	9.59	60
23	2100	0.0	0	21.4	3.0	1347	-0	28500	1.967	3.90	8

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	70.7	561	2.5	.067	0.0	0.0	4.72	37.4	.2
2	0.0	235.0	2749	4.2	.040	0.0	0.0	9.40	109.9	.2
3	0.0	132.6	3059	17.4	.040	.3	0.0	5.31	122.3	.7
4	0.0	153.5	3608	40.8	.040	.5	0.0	6.14	144.3	1.6
5	0.0	179.2	4435	77.8	.040	.8	0.0	7.17	177.4	3.1
6	0.0	192.1	4785	103.0	.040	1.1	0.0	7.69	191.4	4.1
7	0.0	186.3	4891	150.3	.040	1.3	0.0	7.45	195.6	6.0
8	0.0	221.4	5452	238.4	.040	1.6	0.0	8.86	218.1	9.5
9	0.0	211.8	5131	334.5	.040	1.9	0.0	8.47	205.3	13.4
10	0.0	234.4	5601	341.0	.040	2.1	0.0	9.37	224.1	13.6
11	0.0	62.8	503	2.5	.067	0.0	0.0	4.19	33.6	.2
12	0.0	477.5	652	.5	.040	0.0	0.0	19.10	26.1	.0
13	0.0	223.3	5179	723.2	.040	2.8	0.0	8.93	207.2	28.9
14	0.0	213.8	6117	515.9	.040	2.5	0.0	8.55	244.7	20.6
15	0.0	204.1	5721	417.5	.040	2.1	0.0	8.16	228.8	16.7
16	0.0	209.7	5861	342.4	.040	1.8	0.0	8.39	234.5	13.7
17	0.0	198.0	5603	270.6	.040	1.4	0.0	7.92	224.1	10.8
18	0.0	186.7	5389	199.7	.040	1.1	0.0	7.47	215.6	8.0
19	0.0	161.6	4474	95.0	.040	.7	0.0	6.46	178.9	3.8
20	0.0	254.6	3549	49.0	.040	.4	0.0	10.18	142.0	2.0
21	0.0	196.6	2980	9.9	.040	0.0	0.0	7.86	119.2	.4
22	0.0	98.4	651	2.4	.067	0.0	0.0	6.60	43.4	.2
23	0.0	440.6	614	.4	.040	0.0	0.0	17.63	24.6	.0

CYCLE COMPOSITE			
	HC	8.795	GRAM/BHP HR
	CO	159.207	GRAM/BHP HR
	NO2	7.078	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.659	LB/BHP HR

FORD G5000 ENGINE NO E188653
23-MODE EMISSIONS TEST RUN 3 3/30/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	650	0.0	0	19.7	3.2	1452	-0	9000	2.188	10.55	79
2	1400	0.0	0	19.8	7.1	3202	-0	12700	6.822	7.93	56
3	1400	19.0	7	18.3	9.0	4069	-0	4950	5.626	9.33	194
4	1400	40.0	14	16.5	11.7	5321	-0	4300	4.964	9.82	388
5	1400	57.0	20	14.0	14.1	6373	-0	4000	4.736	9.94	536
6	1400	77.0	27	12.2	17.4	7870	-0	3550	4.463	10.15	761
7	1400	95.0	33	10.2	19.2	8691	-0	2950	4.007	10.55	800
8	1400	114.0	40	7.7	21.5	9752	-0	2850	3.447	10.79	1075
9	1400	133.0	47	5.1	24.2	10973	-0	2700	2.886	11.23	1304
10	1400	151.0	53	2.4	26.8	12166	-0	2650	3.303	11.10	1084
11	650	0.0	0	19.9	3.1	1420	-0	8950	2.186	10.65	69
12	1400	0.0	0	21.4	3.4	1542	-0	36000	2.290	5.61	9
13	2100	136.0	71	3.2	33.9	15363	-0	2200	2.201	11.50	1932
14	2100	118.0	62	5.9	32.4	14683	-0	2150	3.056	10.93	1470
15	2100	101.0	53	8.9	28.1	12746	-0	2300	3.355	10.80	1390
16	2100	84.0	44	11.1	25.2	11426	-0	2650	3.630	10.59	1336
17	2100	67.0	35	12.9	22.4	10152	-0	2850	4.014	10.37	1170
18	2100	51.0	27	15.0	18.7	8473	-0	3300	4.521	10.14	908
19	2100	34.0	18	16.9	15.6	7099	-0	3500	4.745	9.76	649
20	2100	17.0	9	18.2	12.4	5638	-0	3700	4.972	9.65	432
21	2100	0.0	0	20.1	9.3	4237	-0	6500	5.239	8.78	117
22	650	0.0	0	20.1	3.2	1433	-0	9000	2.925	9.93	62
23	2100	0.0	0	21.6	3.5	1565	-0	34500	2.009	3.63	8

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	95.8	470	2.8	.067	0.0	0.0	6.39	31.4	.2
2	0.0	253.4	2755	3.7	.040	0.0	0.0	10.16	110.2	.1
3	0.0	130.3	2993	16.9	.040	.3	0.0	5.21	119.7	.7
4	0.0	150.4	3506	45.1	.040	.6	0.0	6.01	140.2	1.8
5	0.0	169.1	4044	75.2	.040	.8	0.0	6.76	161.8	3.0
6	0.0	186.7	4742	132.9	.040	1.1	0.0	7.47	189.7	5.3
7	0.0	172.6	4737	155.5	.040	1.3	0.0	6.91	189.5	6.2
8	0.0	191.4	4675	239.6	.040	1.6	0.0	7.65	187.0	9.6
9	0.0	205.9	4446	330.2	.040	1.9	0.0	8.24	177.8	13.2
10	0.0	219.9	5535	298.5	.040	2.1	0.0	8.79	221.4	11.9
11	0.0	92.6	457	2.4	.067	0.0	0.0	6.17	30.5	.2
12	0.0	482.9	620	.4	.040	0.0	0.0	19.32	24.8	.0
13	0.0	242.8	4906	707.7	.040	2.9	0.0	9.71	196.2	28.3
14	0.0	222.3	6384	504.6	.040	2.5	0.0	8.89	255.4	20.2
15	0.0	203.8	6003	409.0	.040	2.1	0.0	8.15	240.1	16.4
16	0.0	209.1	5786	349.9	.040	1.8	0.0	8.36	231.4	14.0
17	0.0	197.2	5612	268.9	.040	1.4	0.0	7.89	224.5	10.8
18	0.0	186.5	5162	170.3	.040	1.1	0.0	7.46	206.5	6.8
19	0.0	167.3	4581	103.0	.040	.7	0.0	6.69	183.2	4.1
20	0.0	139.1	3777	54.0	.040	.4	0.0	5.57	151.1	2.2
21	0.0	187.7	3056	11.2	.040	0.0	0.0	7.51	122.3	.4
22	0.0	93.8	616	2.1	.067	0.0	0.0	6.26	41.1	.1
23	0.0	594.0	699	.5	.040	0.0	0.0	23.76	28.0	.0

CYCLE COMPOSITE

HC	8.910	GRAM/BHP HR
CO	154.820	GRAM/BHP HR
NO2	6.954	GRAM/BHP HR
ALDE	0.000	GRAM/BHP HR
BSFC	.664	LB/BHP HR

FORD G5000 ENGINE NO E188653
23-MODE EMISSIONS TEST   RUN 4   3/31/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	650	0.0	0	19.3	3.2	1433	-0	8400	1.933	9.41	63
2	1400	0.0	0	19.5	6.9	3112	-0	12600	6.864	7.32	44
3	1400	19.0	7	18.1	8.7	3960	-0	5000	5.599	8.66	175
4	1400	38.0	13	16.3	11.1	5017	-0	4400	5.003	9.05	365
5	1400	57.0	20	14.3	13.5	6137	-0	4000	4.778	9.07	506
6	1400	76.0	27	11.9	16.6	7534	-0	3700	4.503	9.26	[illegible]
7	1400	95.0	33	9.9	18.9	8555	-0	3000	3.950	9.48	718
8	1400	114.0	40	7.5	20.7	9394	-0	2850	3.571	[illegible]	[illegible]
9	1400	133.0	47	5.1	23.8	10796	-0	2550	3.125	10.07	[illegible]
10	1400	154.0	54	2.2	27.2	12352	-0	2500	3.289	[illegible]	[illegible]
11	650	0.0	0	19.8	3.1	1406	-0	8600	2.365	[illegible]	[illegible]
12	1400	0.0	0	21.4	3.2	1456	-0	29000	2.516	[illegible]	10
13	2100	138.0	72	3.1	35.3	15994	-0	2200	2.029	[illegible]	[illegible]
14	2100	118.0	62	6.2	31.2	14148	-0	2300	3.017	[illegible]	[illegible]
15	2100	101.0	53	9.0	27.4	12429	-0	2550	3.234	[illegible]	1405
16	2100	84.0	44	11.4	24.9	11272	-0	2800	3.675	10.50	1303
17	2100	67.0	35	12.9	22.1	10038	-0	3000	4.163	10.17	1161
18	2100	51.0	27	15.0	18.3	8287	-0	3200	4.471	[illegible]	[illegible]
19	2100	34.0	18	16.7	15.5	7049	-0	3600	4.815	[illegible]	[illegible]
20	2100	17.0	9	18.6	12.9	5865	-0	3700	5.093	9.38	[illegible]
21	2100	0.0	0	20.0	9.1	4105	-0	6000	5.132	8.62	[illegible]
22	650	0.0	0	20.0	3.0	1383	-0	7500	2.645	[illegible]	[illegible]
23	2100	0.0	0	21.7	3.5	1579	-0	41000	2.112	9.07	

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	48.8	460	2.4	.067	0.0	0.0	6.59	30.7	.2
2	0.0	253.9	2794	3.3	.040	0.0	0.0	10.16	111.8	.1
3	0.0	134.1	3034	15.6	.040	.3	0.0	5.36	121.4	.6
4	0.0	152.3	3499	42.0	.040	.5	0.0	6.09	139.9	1.7
5	0.0	172.3	4158	72.3	.040	.8	0.0	6.89	166.3	2.9
6	0.0	197.3	4849	112.8	.040	1.1	0.0	7.89	194.0	4.5
7	0.0	186.9	4970	148.5	.040	1.3	0.0	7.47	198.8	5.9
8	0.0	197.6	5001	217.1	.040	1.6	0.0	7.90	200.0	8.7
9	0.0	204.3	5057	306.3	.040	1.9	0.0	8.17	202.3	12.3
10	0.0	223.8	5947	305.4	.040	2.2	0.0	8.95	237.9	12.2
11	0.0	96.7	537	2.4	.067	0.0	0.0	6.45	35.8	[illegible]
12	0.0	371.7	651	[illegible]	.040	0.0	0.0	14.87	26.1	[illegible]
13	0.0	255.6	4762	733.7	.040	2.9	0.0	10.22	190.5	[illegible]
14	0.0	231.0	6121	472.5	.040	2.5	0.0	9.24	244.9	[illegible]
15	0.0	224.5	5752	410.8	.040	2.1	0.0	8.98	230.1	[illegible]
16	0.0	218.4	5791	337.5	.040	1.8	0.0	8.74	231.6	13.5
17	0.0	205.7	5767	264.2	.040	1.4	0.0	8.23	230.7	10.6
18	0.0	179.7	5072	164.6	.040	1.1	0.0	7.19	202.9	6.8
19	0.0	173.0	4675	103.8	.040	.7	0.0	6.92	187.0	4.2
20	0.0	146.2	4065	51.1	.040	.4	0.0	5.85	162.6	2.0
21	0.0	171.6	2964	9.9	.040	0.0	0.0	6.86	118.6	.4
22	0.0	76.7	546	2.1	.067	0.0	0.0	5.11	36.4	.1
23	0.0	629.3	655	.5	.040	0.0	0.0	25.17	26.2	.0

CYCLE COMPOSITE			
	HC	8.893	GRAM/BHP HR
	CO	157.325	GRAM/BHP HR
	NO2	6.762	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.654	LB/BHP HR

FORD G5000 ENGINE NO E188653
23-MODE EMISSIONS TEST RUN 5 3/31/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	650	0.0	0	20.2	3.1	1424	-0	7200	2.412	10.16	65
2	1400	0.0	0	19.8	6.9	3130	-0	14000	6.989	7.61	53
3	1400	19.0	7	18.5	8.4	3810	-0	4700	6.214	8.86	146
4	1400	38.0	13	16.3	10.6	4822	-0	4000	5.323	9.36	346
5	1400	57.0	20	14.5	13.7	6196	-0	3600	4.857	9.66	519
6	1400	76.0	27	12.4	15.6	7094	-0	3300	4.421	9.97	650
7	1400	95.0	33	10.2	17.7	8038	-0	2800	3.872	10.38	809
8	1400	114.0	40	7.6	21.0	9526	-0	2700	3.361	10.61	1186
9	1400	133.0	47	5.0	23.8	10796	-0	2200	2.850	11.05	1285
10	1400	151.0	53	2.6	28.2	12787	-0	2300	3.017	10.84	1068
11	650	0.0	0	20.0	3.2	1456	-0	6800	2.350	9.90	71
12	1400	0.0	0	21.4	3.3	1497	-0	34000	2.461	6.02	11
13	2100	137.0	72	3.6	34.4	15622	-0	2200	2.312	11.49	1745
14	2100	118.0	62	6.8	32.2	14592	-0	2450	3.101	10.83	1448
15	2100	101.0	53	9.2	27.1	12315	-0	2700	3.361	10.61	1371
16	2100	84.0	44	11.4	24.4	11045	-0	3000	3.588	10.59	1282
17	2100	67.0	35	13.4	22.5	10197	-0	3300	4.163	10.17	1095
18	2100	51.0	27	15.0	18.9	8555	-0	3750	4.529	9.96	866
19	2100	34.0	18	17.0	15.8	7149	-0	4050	4.890	9.66	606
20	2100	17.0	9	18.6	12.1	5502	-0	4300	4.820	9.41	373
21	2100	0.0	0	20.2	9.2	4169	-0	6700	5.302	8.69	98
22	650	0.0	0	19.8	3.2	1470	-0	10000	1.691	9.69	64
23	2100	0.0	0	21.5	3.3	1497	-0	33600	2.095	3.98	8

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	77.1	522	2.3	.067	0.0	0.0	5.14	34.8	.2
2	0.0	273.4	2762	3.4	.040	0.0	0.0	10.95	110.5	.1
3	0.0	115.2	3078	11.9	.040	.3	0.0	4.61	123.1	.5
4	0.0	127.9	3438	36.7	.040	.5	0.0	5.12	137.5	1.5
5	0.0	149.9	4086	71.8	.040	.8	0.0	6.00	163.4	2.9
6	0.0	159.0	4304	104.0	.040	1.1	0.0	6.36	172.2	4.2
7	0.0	154.8	4325	148.5	.040	1.3	0.0	6.19	173.0	5.9
8	0.0	180.5	4540	263.3	.040	1.6	0.0	7.22	181.6	10.5
9	0.0	168.2	4401	326.3	.040	1.9	0.0	6.73	176.0	13.1
10	0.0	208.8	5532	321.9	.040	2.1	0.0	8.35	221.3	12.9
11	0.0	76.6	535	2.7	.067	0.0	0.0	5.11	35.7	.2
12	0.0	428.5	626	.5	.040	0.0	0.0	17.14	25.1	.0
13	0.0	245.1	5203	645.4	.040	2.9	0.0	9.81	208.1	25.8
14	0.0	252.2	6449	494.6	.040	2.5	0.0	10.09	258.0	19.8
15	0.0	233.4	5869	393.6	.040	2.1	0.0	9.34	234.8	15.7
16	0.0	228.8	5524	324.6	.040	1.8	0.0	9.15	221.2	13.0
17	0.0	229.4	5847	252.6	.040	1.4	0.0	9.18	233.9	10.1
18	0.0	215.8	5266	165.5	.040	1.1	0.0	8.63	210.6	6.6
19	0.0	193.6	4722	96.2	.040	.7	0.0	7.74	188.9	3.8
20	0.0	161.4	3655	46.5	.040	.4	0.0	6.46	146.2	1.9
21	0.0	190.5	3045	9.2	.040	0.0	0.0	7.62	121.8	.4
22	0.0	118.7	405	2.5	.067	0.0	0.0	7.92	27.0	.2
23	0.0	532.9	671	.4	.040	0.0	0.0	21.32	26.9	.0

CYCLE COMPOSITE			
	HC	8.777	GRAM/BHP HR
	CO	153.528	GRAM/BHP HR
	NO2	6.675	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.653	LB/BHP HR

HERCULES G-2300 ENGINE NO 3319263
23-MODE EMISSIONS TEST RUN 2 6/16/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	600	0.0	0	19.1	2.8	1261	-0	5900	5.344	8.20	35
2	1450	0.0	0	19.3	6.3	2840	-0	3500	3.277	10.62	71
3	1450	19.0	7	16.9	8.8	3974	-0	3900	4.587	10.31	138
4	1450	37.0	13	14.5	12.8	5788	-0	3800	5.022	9.65	259
5	1450	56.0	20	12.3	15.5	7049	-0	3750	5.101	9.38	329
6	1450	74.0	27	10.1	17.3	7838	-0	3600	4.973	9.48	412
7	1450	92.0	33	8.1	19.9	9031	-0	3500	4.769	10.12	474
8	1450	108.0	39	6.2	24.8	11263	-0	3200	4.600	10.04	605
9	1450	128.0	46	3.7	26.5	12025	-0	3050	4.732	9.67	802
10	1450	148.0	54	1.5	33.2	15069	-0	2850	7.195	8.53	385
11	600	0.0	0	18.9	2.7	1207	-0	9600	6.681	6.89	25
12	1450	0.0	0	21.0	2.8	1261	-0	54000	2.667	3.93	8
13	2400	126.0	76	2.3	38.7	17568	-0	1850	3.602	10.68	1031
14	2400	108.0	65	4.2	35.6	16135	-0	2050	4.194	10.62	928
15	2400	94.0	56	6.2	32.1	14579	-0	2200	4.604	9.95	714
16	2400	76.0	46	8.4	27.3	12374	-0	2200	4.662	9.95	616
17	2400	62.0	37	10.4	23.9	10859	-0	2500	4.875	10.28	473
18	2400	45.0	27	12.6	22.0	9961	-0	2450	5.026	9.56	389
19	2400	31.0	19	14.3	18.2	8242	-0	2700	5.541	9.25	259
20	2400	15.0	9	16.4	14.2	6459	-0	2650	5.282	9.36	156
21	2400	0.0	0	18.7	10.0	4518	-0	2700	4.807	9.32	87
22	600	0.0	0	19.0	2.4	1089	-0	7000	5.853	7.39	31
23	2400	0.0	0	21.0	2.6	1161	-0	43800	.955	2.88	8

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	52.6	963	1.0	.067	0.0	0.0	3.51	64.2	.1
2	0.0	69.7	1319	4.7	.040	0.0	0.0	2.79	52.8	.2
3	0.0	101.4	2408	11.9	.040	.3	0.0	4.05	96.3	.5
4	0.0	146.2	3902	33.1	.040	.5	0.0	5.85	156.1	1.3
5	0.0	177.9	4889	51.8	.040	.8	0.0	7.12	195.6	2.1
6	0.0	190.5	5316	72.3	.040	1.1	0.0	7.62	212.6	2.9
7	0.0	207.5	5711	93.3	.040	1.3	0.0	8.30	228.4	3.7
8	0.0	241.0	6996	151.3	.040	1.6	0.0	9.64	279.8	6.1
9	0.0	249.3	7814	217.6	.040	1.9	0.0	9.97	312.6	8.7
10	0.0	268.3	13681	120.2	.040	2.1	0.0	10.73	547.2	4.8
11	0.0	79.7	1121	.7	.067	0.0	0.0	5.32	74.7	.0
12	0.0	567.8	566	.3	.040	0.0	0.0	22.71	22.7	.0
13	0.0	224.6	8833	415.6	.040	3.0	0.0	8.98	353.3	16.6
14	0.0	220.2	9099	330.8	.040	2.6	0.0	8.81	364.0	13.2
15	0.0	217.1	9176	233.9	.040	2.3	0.0	8.68	367.0	9.4
16	0.0	183.6	7858	170.6	.040	1.8	0.0	7.34	314.3	6.8
17	0.0	176.2	6940	110.6	.040	1.5	0.0	7.05	277.6	4.4
18	0.0	164.6	6819	86.8	.040	1.1	0.0	6.58	272.8	3.5
19	0.0	147.7	6124	47.0	.040	.7	0.0	5.91	245.0	1.9
20	0.0	114.8	4622	22.4	.040	.4	0.0	4.59	184.9	.9
21	0.0	84.7	3047	9.1	.040	0.0	0.0	3.39	121.9	.4
22	0.0	54.7	923	.8	.067	0.0	0.0	3.65	61.6	.1
23	0.0	618.8	273	.4	.040	0.0	0.0	24.75	10.9	.0

CYCLE COMPOSITE			
	HC	8.157	GRAM/BHP HR
	CO	209.708	GRAM/BHP HR
	NO2	3.811	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.706	LB/BHP HR

HERCULES G-2300 ENGINE NO 3319263
23-MODE EMISSIONS TEST   RUN 3   6/19/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	WET CONCENTRATION CO	WET CONCENTRATION CO2	NO
1	600	0.0	0	18.6	3.2	1438	-0	5750	5.935	8.24	34
2	1450	0.0	0	18.9	5.9	2685	-0	3850	3.879	10.84	66
3	1450	19.0	7	16.6	9.5	4318	-0	4250	4.306	10.52	155
4	1450	38.0	14	14.4	12.5	5665	-0	4350	4.990	10.27	236
5	1450	56.0	20	12.3	16.6	7552	-0	4000	5.122	10.08	318
6	1450	74.0	27	9.9	19.1	8646	-0	3500	5.103	10.44	385
7	1450	94.0	34	7.5	21.4	9716	-0	3450	4.760	10.29	581
8	1450	112.0	41	5.4	22.5	10206	-0	3050	4.636	10.48	526
9	1450	130.0	47	3.2	27.6	12533	-0	3150	4.618	10.86	814
10	1450	148.0	54	1.4	33.8	15309	-0	3350	6.658	9.41	362
11	600	0.0	0	18.4	3.0	1356	-0	7400	6.763	7.85	30
12	1450	0.0	0	20.9	3.3	1501	-0	53600	3.085	4.28	9
13	2400	127.0	76	2.0	39.5	17899	-0	2300	3.537	11.07	1146
14	2400	110.0	66	3.7	37.5	17001	-0	2700	4.190	10.72	1013
15	2400	94.0	56	6.0	33.2	15055	-0	2800	4.467	10.59	807
16	2400	80.0	48	8.2	28.5	12941	-0	3050	4.645	10.31	625
17	2400	63.0	38	10.3	24.2	10982	-0	3150	4.751	10.47	526
18	2400	48.0	29	12.0	21.8	9902	-0	3200	4.870	10.38	429
19	2400	32.0	19	14.1	16.8	7616	-0	3400	5.113	10.26	253
20	2400	17.0	10	16.0	14.1	6378	-0	3600	5.264	9.71	164
21	2400	0.0	0	18.3	10.0	4554	-0	3000	4.853	9.58	87
22	600	0.0	0	18.8	3.3	1501	-0	7000	5.751	8.01	34
23	2400	0.0	0	20.9	2.6	1161	-0	37200	.914	3.22	7

MODE	CALCULATED GRAM/HR ALDE.	CALCULATED GRAM/HR HC	CALCULATED GRAM/HR CO	CALCULATED GRAM/HR NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	WEIGHTED GRAM/HR HC	WEIGHTED GRAM/HR CO	WEIGHTED GRAM/HR NO2
1	0.0	56.1	1169	1.1	.067	0.0	0.0	3.74	78.0	.1
2	0.0	68.4	1393	3.9	.040	0.0	0.0	2.74	55.7	.2
3	0.0	120.4	2463	14.6	.040	.3	0.0	4.81	98.5	.6
4	0.0	157.0	3638	28.3	.040	.6	0.0	6.28	145.5	1.1
5	0.0	193.6	5008	51.1	.040	.8	0.0	7.74	200.3	2.0
6	0.0	190.4	5608	69.6	.040	1.1	0.0	7.62	224.3	2.8
7	0.0	217.7	6067	121.7	.040	1.4	0.0	8.71	242.7	4.9
8	0.0	201.8	6196	115.6	.040	1.6	0.0	8.07	247.8	4.6
9	0.0	249.9	7401	214.4	.040	1.9	0.0	10.00	296.0	8.6
10	0.0	312.7	12554	112.1	.040	2.1	0.0	12.51	502.1	4.5
11	0.0	65.4	1207	.9	.067	0.0	0.0	4.36	80.5	.1
12	0.0	632.6	735	.3	.040	0.0	0.0	25.30	29.4	.0
13	0.0	277.5	8620	459.0	.040	3.0	0.0	11.10	344.8	18.4
14	0.0	302.5	9481	376.8	.040	2.6	0.0	12.10	379.3	15.1
15	0.0	274.8	8854	263.0	.040	2.3	0.0	10.99	354.2	10.5
16	0.0	258.7	7959	175.9	.040	1.9	0.0	10.35	318.3	7.0
17	0.0	222.6	6782	123.4	.040	1.5	0.0	8.90	271.3	4.9
18	0.0	203.6	6258	90.7	.040	1.2	0.0	8.14	250.3	3.6
19	0.0	164.8	5006	40.7	.040	.8	0.0	6.59	200.2	1.6
20	0.0	149.7	4423	22.6	.040	.4	0.0	5.99	176.9	.9
21	0.0	92.8	3031	8.9	.040	0.0	0.0	3.71	121.2	.4
22	0.0	72.7	1206	1.2	.067	0.0	0.0	4.85	80.4	.1
23	0.0	549.9	273	.3	.040	0.0	0.0	22.00	10.9	.0

CYCLE COMPOSITE

HC	8.816	GRAM/BHP HR
CO	200.947	GRAM/BHP HR
NO2	3.923	GRAM/BHP HR
ALDE	0.000	GRAM/BHP HR
BSFC	.710	LB/BHP HR

HERCULES G-2300 ENGINE NO 3319263
23-MODE EMISSIONS TEST RUN 4 6/19/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	600	0.0	0	18.7	3.3	1501	-0	6400	5.787	7.39	35
2	1450	0.0	0	19.1	6.1	2776	-0	3400	3.159	10.36	78
3	1450	17.0	6	17.5	9.5	4318	-0	3550	3.758	10.30	157
4	1450	38.0	14	14.6	12.5	5665	-0	3950	4.812	9.23	326
5	1450	56.0	20	12.2	16.4	7421	-0	3700	5.110	9.21	416
6	1450	75.0	27	9.9	18.7	8505	-0	3500	4.924	9.31	445
7	1450	93.0	34	7.5	19.9	9004	-0	3300	4.508	9.69	499
8	1450	112.0	41	5.2	21.8	9902	-0	3000	4.554	9.78	553
9	1450	131.0	47	3.3	27.2	12320	-0	2900	4.558	9.69	803
10	1450	148.0	54	1.7	34.4	15622	-0	3100	6.337	8,69	474
11	600	0.0	0	18.7	3.2	1442	-0	8000	7.400	6.91	28
12	1450	0.0	0	20.9	3.5	1569	-0	48800	3.337	4.83	12
13	2400	125.0	75	2.1	38.8	17595	-0	2350	3.987	9.39	986
14	2400	111.0	67	3.6	37.5	17010	-0	2300	4.473	9.18	1070
15	2400	94.0	56	6.4	31.6	14352	-0	2800	4.886	8.89	676
16	2400	80.0	48	7.9	29.0	13145	-0	2950	5.442	8.84	499
17	2400	63.0	38	10.3	25.0	11340	-0	3100	5.172	9.12	510
18	2400	47.0	28	12.2	22.2	10052	-0	3100	5.065	8.80	469
19	2400	33.0	20	14.1	18.7	8505	-0	3300	5.314	8.78	326
20	2400	17.0	10	16.3	14.1	6378	-0	3450	5.517	8.67	169
21	2400	0.0	0	18.5	10.0	4554	-0	3300	4.914	8.32	87
22	600	0.0	0	18.8	2.6	1161	-0	8400	5.829	6.66	32
23	2400	0.0	0	20.9	2.5	1134	-0	46400	.887	3.05	8

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	69.5	1270	1.3	.067	0.0	0.0	4.64	84.7	.1
2	0.0	68.1	1278	5.2	.040	0.0	0.0	2.72	51.1	.2
3	0.0	106.4	2274	15.6	.040	.2	0.0	4.25	91.0	.6
4	0.0	155.0	3814	42.5	.040	.6	0.0	6.20	152.6	1.7
5	0.0	187.0	5216	69.9	.040	.8	0.0	7.48	208.6	2.8
6	0.0	204.1	5801	86.1	.040	1.1	0.0	8.17	232.0	3.4
7	0.0	204.5	5642	102.7	.040	1.3	0.0	8.18	225.7	4.1
8	0.0	203.0	6226	124.4	.040	1.6	0.0	8.12	249.1	5.0
9	0.0	245.8	7803	226.0	.040	1.9	0.0	9.83	312.1	9.0
10	0.0	315.8	13041	160.2	.040	2.1	0.0	12.63	521.6	6.4
11	0.0	76.3	1427	.9	.067	0.0	0.0	5.09	95.2	.1
12	0.0	586.8	811	.5	.040	0.0	0.0	23.47	32.4	.0
13	0.0	303.7	10408	422.4	.040	3.0	0.0	12.15	416.3	16.9
14	0.0	281.8	11069	435.3	.040	2.7	0.0	11.27	442.8	17.4
15	0.0	285.9	10077	229.2	.040	2.3	0.0	11.43	403.1	9.2
16	0.0	266.0	9910	149.4	.040	1.9	0.0	10.64	396.4	6.0
17	0.0	240.7	8113	131.6	.040	1.5	0.0	9.63	324.5	5.3
18	0.0	219.9	7257	110.4	.040	1.1	0.0	8.80	290.3	4.4
19	0.0	194.7	6331	63.9	.040	.8	0.0	7.79	253.3	2.6
20	0.0	151.4	4891	24.7	.040	.4	0.0	6.06	195.6	1.0
21	0.0	110.8	3333	9.7	.040	0.0	0.0	4.43	133.3	.4
22	0.0	73.2	1026	.9	.067	0.0	0.0	4.88	68.4	.1
23	0.0	613.9	237	.3	.040	0.0	0.0	24.55	9.5	.0

CYCLE COMPOSITE			
	HC	9.079	GRAM/BHP HR
	CO	221.824	GRAM/BHP HR
	NO2	4.130	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.709	LB/BHP HR

HERCULES G-2300 ENGINE NO 3319263
23-MODE EMISSIONS TEST RUN 5 6/20/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	600	0.0	0	18.7	3.0	1343	-0	7300	6.606	8.02	35
2	1450	0.0	0	18.9	6.3	2835	-0	4000	3.301	11.38	69
3	1450	19.0	7	16.4	9.5	4323	-0	4300	4.508	10.78	163
4	1450	38.0	14	14.6	12.5	5670	-0	4000	4.914	10.64	257
5	1450	57.0	21	12.2	16.1	7289	-0	4050	5.050	10.36	360
6	1450	75.0	27	9.9	19.7	8954	-0	3750	4.742	10.66	525
7	1450	93.0	34	7.9	22.1	10038	-0	3950	4.852	10.74	449
8	1450	113.0	41	5.1	25.2	11435	-0	3450	4.486	11.25	598
9	1450	130.0	47	3.4	27.2	12320	-0	3400	4.685	10.67	686
10	1450	149.0	54	1.7	31.8	14443	-0	3700	6.885	9.56	329
11	600	0.0	0	18.6	3.1	1415	-0	8100	6.903	8.16	31
12	1450	0.0	0	20.9	3.6	1619	-0	51200	3.396	4.39	12
13	2400	126.0	76	2.1	40.2	18226	-0	2700	3.330	10.53	1090
14	2400	110.0	66	3.5	36.8	16715	-0	3100	4.786	9.75	779
15	2400	95.0	57	5.5	32.7	14815	-0	3100	4.782	9.84	670
16	2400	79.0	47	7.6	30.4	13771	-0	3400	5.178	10.25	471
17	2400	63.0	38	9.8	26.7	12111	-0	3150	4.902	9.74	529
18	2400	47.0	28	12.1	21.8	9902	-0	3300	5.083	9.73	388
19	2400	33.0	20	14.3	17.9	8101	-0	3500	5.206	9.71	254
20	2400	17.0	10	16.1	14.7	6691	-0	3700	5.517	9.69	142
21	2400	0.0	0	18.4	10.0	4554	-0	3600	5.039	9.30	79
22	600	0.0	0	18.7	2.7	1216	-0	8400	5.831	7.77	33
23	2400	0.0	0	20.9	2.8	1293	-0	48000	1.075	2.37	8

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	63.8	1166	1.0	.067	0.0	0.0	4.26	77.8	.1
2	0.0	75.2	1253	4.3	.040	0.0	0.0	3.01	50.1	.2
3	0.0	118.3	2505	14.9	.040	.3	0.0	4.73	100.2	.6
4	0.0	142.1	3527	30.3	.040	.6	0.0	5.69	141.1	1.2
5	0.0	186.7	4703	55.1	.040	.8	0.0	7.47	188.1	2.2
6	0.0	212.8	5437	98.9	.040	1.1	0.0	8.51	217.5	4.0
7	0.0	248.0	6154	93.7	.040	1.3	0.0	9.92	246.2	3.7
8	0.0	245.3	6442	141.2	.040	1.6	0.0	9.81	257.7	5.6
9	0.0	267.0	7431	178.9	.040	1.9	0.0	10.68	297.2	7.2
10	0.0	317.9	11948	93.8	.040	2.2	0.0	12.71	477.9	3.8
11	0.0	72.2	1243	.9	.067	0.0	0.0	4.82	82.9	.1
12	0.0	642.4	861	.5	.040	0.0	0.0	25.70	34.4	.0
13	0.0	348.2	8676	466.6	.040	3.0	0.0	13.93	347.0	18.7
14	0.0	348.9	10882	291.1	.040	2.6	0.0	13.96	435.3	11.6
15	0.0	307.5	9583	220.7	.040	2.3	0.0	12.30	383.3	8.8
16	0.0	296.9	9133	136.7	.040	1.9	0.0	11.88	365.3	5.5
17	0.0	255.0	8016	142.2	.040	1.5	0.0	10.20	320.6	5.7
18	0.0	215.8	6716	84.3	.040	1.1	0.0	8.63	268.6	3.4
19	0.0	185.7	5579	44.8	.040	.8	0.0	7.43	223.2	1.8
20	0.0	159.0	4788	20.2	.040	.4	0.0	6.36	191.5	.8
21	0.0	111.5	3154	8.1	.040	0.0	0.0	4.46	126.2	.3
22	0.0	70.7	991	.9	.067	0.0	0.0	4.72	66.1	.1
23	0.0	752.5	340	.4	.040	0.0	0.0	30.10	13.6	.0

CYCLE COMPOSITE			
	HC	9.861	GRAM/BHP HR
	CO	209.444	GRAM/BHP HR
	NO2	3.636	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.721	LB/BHP HR

J.I. CASE 159 G ENGINE NO 2707350
23-MODE EMISSIONS TEST RUN 3 2/11/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	WET CONCENTRATION CO	WET CONCENTRATION CO2	NO
1	500	0.0	0	17.9	2.6	1179	-0	4900	7.301	7.28	45
2	1400	0.0	0	17.4	6.1	2767	-0	5900	8.216	6.79	68
3	1400	12.0	4	16.3	7.0	3175	-0	5350	8.020	7.16	77
4	1400	23.5	8	14.5	9.2	4173	-0	4200	7.483	7.95	124
5	1400	35.0	12	12.8	10.3	4672	-0	3900	7.101	8.06	168
6	1400	47.0	16	10.6	11.6	5262	-0	3650	6.862	8.40	180
7	1400	58.0	20	9.1	12.9	5851	-0	3450	7.604	10.36	388
8	1400	70.0	24	6.8	14.7	6668	-0	3200	7.372	10.48	376
9	1400	81.0	28	4.1	16.3	7394	-0	3100	7.054	10.70	652
10	1400	92.5	32	2.2	17.7	8029	-0	2900	5.910	7.54	464
11	500	0.0	0	18.5	2.6	1179	-0	4800	7.449	7.35	46
12	1400	0.0	0	20.6	2.9	1315	-0	54400	3.533	4.32	13
13	2100	79.5	42	5.6	22.9	10387	-0	2550	5.566	9.25	647
14	2100	70.0	37	7.1	21.6	9798	-0	2600	5.951	9.05	491
15	2100	60.0	31	8.9	18.8	8528	-0	2700	6.100	8.87	388
16	2100	50.0	26	10.5	17.2	7802	-0	2850	6.219	8.78	349
17	2100	40.0	21	12.2	14.8	6713	-0	2850	6.292	8.77	379
18	2100	30.0	16	13.6	13.0	5897	-0	2800	6.432	8.59	319
19	2100	20.0	10	14.9	11.7	5307	-0	2850	6.862	8.40	172
20	2100	10.0	5	15.7	11.1	5035	-0	2950	7.403	7.96	104
21	2100	0.0	0	16.2	10.4	4717	-0	2950	7.409	7.88	94
22	500	0.0	0	18.9	2.4	1089	-0	4500	6.780	7.47	46
23	2100	0.0	0	20.7	3.1	1406	-0	75200	1.777	2.52	8

MODE	CALCULATED GRAM/HR ALDE.	CALCULATED GRAM/HR HC	CALCULATED GRAM/HR CO	CALCULATED GRAM/HR NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	WEIGHTED GRAM/HR HC	WEIGHTED GRAM/HR CO	WEIGHTED GRAM/HR NO2
1	0.0	38.3	1154	1.2	.067	0.0	0.0	2.56	77.0	.1
2	0.0	104.7	2945	4.0	.040	0.0	0.0	4.19	117.8	.2
3	0.0	108.1	3273	5.2	.040	.2	0.0	4.32	130.9	.2
4	0.0	110.5	3978	10.9	.040	.3	0.0	4.42	159.1	.4
5	0.0	117.1	4308	16.7	.040	.5	0.0	4.69	172.3	.7
6	0.0	122.9	4667	20.2	.040	.7	0.0	4.92	186.7	.8
7	0.0	110.2	4908	41.1	.040	.8	0.0	4.41	196.3	1.6
8	0.0	117.4	5465	45.8	.040	1.0	0.0	4.70	218.6	1.8
9	0.0	126.9	5833	88.6	.040	1.1	0.0	5.08	233.3	3.5
10	0.0	169.5	6977	90.0	.040	1.3	0.0	6.78	279.1	3.6
11	0.0	37.1	1162	1.2	.067	0.0	0.0	2.47	77.5	.1
12	0.0	538.3	706	.4	.040	0.0	0.0	21.53	28.2	.0
13	0.0	175.7	7749	148.1	.040	1.7	0.0	7.03	310.0	5.9
14	0.0	166.9	7717	104.6	.040	1.5	0.0	6.68	308.7	4.2
15	0.0	151.1	6897	72.0	.040	1.3	0.0	6.05	275.9	2.9
16	0.0	145.5	6414	59.1	.040	1.0	0.0	5.82	256.6	2.4
17	0.0	124.7	5559	55.0	.040	.8	0.0	4.99	222.4	2.2
18	0.0	107.9	5006	40.8	.040	.6	0.0	4.32	200.2	1.6
19	0.0	97.3	4732	19.5	.040	.4	0.0	3.89	189.3	.8
20	0.0	94.9	4808	11.1	.040	.2	0.0	3.79	192.3	.4
21	0.0	89.3	4530	9.5	.040	0.0	0.0	3.57	181.2	.4
22	0.0	33.3	1014	1.1	.067	0.0	0.0	2.22	67.6	.1
23	0.0	895.2	427	.3	.040	0.0	0.0	35.81	17.1	.0

CYCLE COMPOSITE			
	HC	11.495	GRAM/BHP HR
	CO	305.473	GRAM/BHP HR
	NO2	2.530	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.793	LB/BHP HR

J.I. CASE 159 G ENGINE NO 2707350
23-MODE EMISSIONS TEST   RUN 4   2/11/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	500	0.0	0	18.7	2.6	1179	-0	5000	6.710	7.55	46
2	1400	0.0	0	17.9	6.3	2858	-0	6100	8.088	7.30	65
3	1400	11.5	4	16.7	7.5	3402	-0	5600	7.800	7.85	94
4	1400	23.0	8	15.1	8.9	4037	-0	4550	7.386	8.20	140
5	1400	35.0	12	13.6	10.2	4627	-0	4400	7.151	8.38	172
6	1400	46.0	16	11.8	11.4	5171	-0	4200	6.917	8.64	218
7	1400	58.5	20	9.1	13.4	6078	-0	3750	6.133	9.11	404
8	1400	70.5	25	7.0	14.6	6623	-0	3500	5.936	9.30	412
9	1400	81.0	28	4.8	16.3	7394	-0	3400	5.551	9.51	710
10	1400	92.5	32	2.5	18.0	8165	-0	3100	5.489	9.60	516
11	500	0.0	0	19.1	2.7	1225	-0	5100	7.274	7.66	50
12	1400	0.0	0	20.5	2.9	1315	-0	52800	3.764	4.37	9
13	2100	79.5	42	5.5	23.3	10569	-0	2900	5.664	9.67	708
14	2100	70.0	37	7.5	21.7	9843	-0	3050	6.187	9.28	514
15	2100	60.0	31	8.8	19.5	8845	-0	3150	6.198	9.11	408
16	2100	50.0	26	10.4	17.7	8029	-0	3250	6.400	9.09	374
17	2100	40.0	21	12.1	16.1	7303	-0	3200	6.400	9.09	407
18	2100	30.5	16	13.3	14.2	6441	-0	3200	6.335	9.10	407
19	2100	20.5	11	15.3	12.1	5489	-0	3200	6.834	8.80	197
20	2100	9.0	5	16.3	11.2	5080	-0	3250	7.460	8.27	109
21	2100	0.0	0	16.5	10.7	4854	-0	3300	6.795	8.33	108
22	500	0.0	0	19.1	2.8	1270	-0	4950	7.569	7.87	53
23	2100	0.0	0	20.9	3.2	1452	-0	84000	1.653	1.93	8

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	39.9	1083	1.2	.067	0.0	0.0	2.66	72.2	.1
2	0.0	109.0	2919	3.9	.040	0.0	0.0	4.36	116.7	.2
3	0.0	117.5	3306	6.6	.040	.2	0.0	4.70	132.3	.3
4	0.0	114.5	3755	11.7	.040	.3	0.0	4.58	150.2	.5
5	0.0	127.5	4186	16.6	.040	.5	0.0	5.10	167.4	.7
6	0.0	135.9	4523	23.5	.040	.6	0.0	5.44	180.9	.9
7	0.0	145.9	4820	52.2	.040	.8	0.0	5.84	192.8	2.1
8	0.0	148.7	5094	58.2	.040	1.0	0.0	5.95	203.8	2.3
9	0.0	163.2	5383	113.2	.040	1.1	0.0	6.53	215.3	4.5
10	0.0	164.3	5878	90.9	.040	1.3	0.0	6.57	235.1	3.6
11	0.0	40.4	1165	1.3	.067	0.0	0.0	2.70	77.7	.1
12	0.0	517.6	745	.3	.040	0.0	0.0	20.71	29.8	.0
13	0.0	196.2	7739	159.0	.040	1.7	0.0	7.85	309.5	6.4
14	0.0	190.3	7799	106.5	.040	1.5	0.0	7.61	312.0	4.3
15	0.0	178.4	7089	76.7	.040	1.3	0.0	7.13	283.6	3.1
16	0.0	165.0	6563	63.1	.040	1.0	0.0	6.60	262.5	2.5
17	0.0	147.8	5972	62.4	.040	.8	0.0	5.91	238.9	2.5
18	0.0	130.9	5233	55.3	.040	.6	0.0	5.23	209.3	2.2
19	0.0	110.1	4749	22.5	.040	.4	0.0	4.40	190.0	.9
20	0.0	102.8	4768	11.5	.040	.2	0.0	4.11	190.7	.5
21	0.0	103.7	4312	11.3	.040	0.0	0.0	4.15	172.5	.5
22	0.0	39.5	1219	1.4	.067	0.0	0.0	2.63	81.3	.1
23	0.0	1017.2	404	.3	.040	0.0	0.0	40.69	16.2	.0

CYCLE COMPOSITE			
	HC	12.794	GRAM/BHP HR
	CO	301.513	GRAM/BHP HR
	NO2	2.841	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.814	LB/BHP HR

J.I. CASE 159 G ENGINE NO 2707350
23-MODE EMISSIONS TEST RUN 5 2/15/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	500	0.0	0	17.6	2.8	1270	-0	6500	6.957	7.02	48
2	1400	0.0	0	18.0	5.7	2586	-0	10200	9.054	6.10	38
3	1400	12.0	4	17.3	6.4	2903	-0	8200	9.130	6.30	46
4	1400	23.5	8	14.5	8.7	3946	-0	5900	8.792	7.03	84
5	1400	35.0	12	12.8	9.6	4355	-0	5700	8.434	7.20	104
6	1400	46.0	16	10.6	11.9	5398	-0	5500	8.081	7.38	133
7	1400	58.5	20	8.4	13.9	6305	-0	4950	7.403	7.96	202
8	1400	70.0	24	6.1	15.6	7076	-0	4650	7.101	8.06	249
9	1400	81.0	28	3.8	17.5	7938	-0	4200	6.367	8.60	465
10	1400	91.0	32	2.3	17.9	8119	-0	4050	6.505	8.59	323
11	500	0.0	0	18.6	2.2	998	-0	6200	7.307	7.21	50
12	1400	0.0	0	20.6	3.1	1406	-0	52800	3.474	4.76	15
13	2100	80.0	42	4.0	24.0	10886	-0	2200	5.689	9.24	560
14	2100	70.0	37	5.8	22.8	10342	-0	2300	6.078	8.95	474
15	2100	60.0	31	8.3	19.8	8981	-0	2550	6.873	8.24	292
16	2100	50.0	26	10.0	17.5	7938	-0	4200	7.023	8.15	275
17	2100	40.5	21	11.4	16.2	7348	-0	4200	7.035	7.99	293
18	2100	30.0	16	13.3	13.8	6260	-0	4250	7.343	7.81	232
19	2100	20.5	11	14.8	11.7	5307	-0	4800	8.434	7.20	86
20	2100	11.0	6	16.5	10.3	4672	-0	4600	8.533	7.05	77
21	2100	0.0	0	18.4	8.1	3674	-0	11000	7.276	6.63	82
22	500	0.0	0	20.1	2.2	998	-0	6700	6.083	6.86	42
23	2100	0.0	0	21.2	3.1	1406	-0	87200	2.649	2.45	10

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	56.4	1220	1.4	.067	0.0	0.0	3.77	81.4	.1
2	0.0	163.0	2923	2.0	.040	0.0	0.0	6.52	116.9	.1
3	0.0	146.5	3295	2.7	.040	.2	0.0	5.86	131.8	.1
4	0.0	141.8	4269	6.7	.040	.3	0.0	5.67	170.8	.3
5	0.0	153.2	4578	9.3	.040	.5	0.0	6.13	183.1	.4
6	0.0	185.4	5504	14.9	.040	.6	0.0	7.42	220.2	.6
7	0.0	196.8	5945	26.6	.040	.8	0.0	7.87	237.8	1.1
8	0.0	210.5	6494	37.5	.040	1.0	0.0	8.42	259.8	1.5
9	0.0	216.7	6636	79.7	.040	1.1	0.0	8.67	265.4	3.2
10	0.0	212.2	6884	56.1	.040	1.3	0.0	8.49	275.4	2.2
11	0.0	40.9	973	1.1	.067	0.0	0.0	2.73	64.9	.1
12	0.0	549.5	730	.5	.040	0.0	0.0	21.98	29.2	.0
13	0.0	158.1	8258	133.7	.040	1.7	0.0	6.32	330.3	5.3
14	0.0	155.9	8320	106.5	.040	1.5	0.0	6.23	332.8	4.3
15	0.0	149.0	8113	56.7	.040	1.3	0.0	5.96	324.5	2.3
16	0.0	213.8	7222	46.5	.040	1.0	0.0	8.55	288.9	1.9
17	0.0	199.8	6761	46.2	.040	.9	0.0	7.99	270.4	1.8
18	0.0	170.8	5961	31.0	.040	.6	0.0	6.83	238.5	1.2
19	0.0	158.1	5610	9.4	.040	.4	0.0	6.32	224.4	.4
20	0.0	133.9	5019	7.4	.040	.2	0.0	5.36	200.8	.3
21	0.0	269.3	3598	[illegible]	.040	0.0	0.0	10.77	143.9	.3
22	0.0	49.1	901	1.0	.067	0.0	0.0	3.28	60.1	.1
23	0.0	887.4	545	.3	.040	0.0	0.0	35.50	21.8	.0

CYCLE COMPOSITE			
	HC	14.631	GRAM/BHP HR
	CO	332.815	GRAM/BHP HR
	NO2	2.043	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.802	LB/BHP HR

J.I. CASE 159 G ENGINE NO 2707350
23-MODE EMISSIONS TEST RUN 6 2/16/72

MODE	SPEED	DYNA. LOAD	HP	MAN. VAC.	FUEL RATE LB/HR	FUEL RATE GM/HR	ALDE.	WET CONCENTRATION HC	CO	CO2	NO
1	500	0.0	0	19.6	2.6	1179	-0	7000	6.150	6.71	41
2	1400	0.0	0	19.2	4.7	2132	-0	9500	8.071	6.51	40
3	1400	11.5	4	17.4	6.5	2948	-0	6400	8.545	6.91	68
4	1400	23.0	8	15.6	7.8	3538	-0	5200	8.248	7.37	107
5	1400	34.5	12	13.5	10.3	4672	-0	4700	7.652	7.71	150
6	1400	46.5	16	11.3	11.6	5262	-0	4550	7.483	7.95	187
7	1400	58.0	20	8.9	13.4	6078	-0	4100	6.569	8.58	344
8	1400	70.0	24	6.8	14.8	6713	-0	3800	6.224	8.70	358
9	1400	81.5	29	4.3	17.0	7711	-0	3550	5.886	9.06	603
10	1400	91.0	32	2.8	17.9	8119	-0	3450	6.003	9.13	463
11	500	0.0	0	19.9	2.4	1089	-0	6600	6.541	6.90	47
12	1400	0.0	0	20.5	3.0	1361	-0	55200	3.723	4.25	13
13	2100	74.5	39	5.1	24.0	10886	-0	3150	6.013	8.96	582
14	2100	66.0	35	6.5	21.7	9843	-0	3300	6.505	8.59	396
15	2100	55.0	29	8.2	19.3	8754	-0	3450	6.868	8.32	292
16	2100	46.5	24	9.9	17.7	8029	-0	3550	6.945	8.23	311
17	2100	38.0	20	11.6	15.2	6895	-0	3650	6.857	8.48	343
18	2100	27.5	14	13.4	13.0	5897	-0	3650	7.320	8.13	189
19	2100	19.5	10	14.6	12.1	5489	-0	3650	7.811	7.70	110
20	2100	9.5	5	16.5	9.8	4445	-0	4300	8.002	7.38	87
21	2100	0.0	0	18.2	7.2	3266	-0	14800	7.163	6.16	79
22	500	0.0	0	19.7	2.5	1134	-0	6900	6.414	6.84	40
23	2100	0.0	0	21.2	2.9	1315	-0	85600	2.721	2.55	10

MODE	CALCULATED GRAM/HR ALDE.	HC	CO	NO2	WT. FAC.	HP	WEIGHTED GRAM/HR ALDE.	HC	CO	NO2
1	0.0	60.9	1081	1.2	.067	0.0	0.0	4.06	72.1	.1
2	0.0	130.4	2237	1.8	.040	0.0	0.0	5.21	89.5	.1
3	0.0	117.3	3162	4.1	.040	.2	0.0	4.69	126.5	.2
4	0.0	114.0	3653	7.8	.040	.3	0.0	4.56	146.1	.3
5	0.0	138.7	4561	14.7	.040	.5	0.0	5.55	182.4	.6
6	0.0	150.6	5005	20.5	.040	.7	0.0	6.03	200.2	.8
7	0.0	160.2	5183	44.6	.040	.8	0.0	6.41	207.3	1.8
8	0.0	166.7	5516	52.1	.040	1.0	0.0	6.67	220.6	2.1
9	0.0	178.9	5993	101.0	.040	1.1	0.0	7.16	239.7	4.0
10	0.0	181.0	6363	80.6	.040	1.3	0.0	7.24	254.5	3.2
11	0.0	51.0	1020	1.2	.067	0.0	0.0	3.40	68.0	.1
12	0.0	556.6	758	.4	.040	0.0	0.0	22.27	30.3	.0
13	0.0	224.3	8650	137.5	.040	1.6	0.0	8.97	346.0	5.5
14	0.0	210.6	8387	83.9	.040	1.4	0.0	8.43	335.5	3.4
15	0.0	194.4	7819	54.7	.040	1.2	0.0	7.78	312.7	2.2
16	0.0	183.5	7251	53.4	.040	1.0	0.0	7.34	290.0	2.1
17	0.0	160.3	6082	50.0	.040	.8	0.0	6.41	243.3	2.0
18	0.0	136.1	5515	23.3	.040	.6	0.0	5.45	220.6	.9
19	0.0	126.2	5455	12.6	.040	.4	0.0	5.05	218.2	.5
20	0.0	120.9	4543	8.2	.040	.2	0.0	4.83	181.7	.3
21	0.0	326.6	3193	5.8	.040	0.0	0.0	13.06	127.7	.2
22	0.0	56.1	1054	1.1	.067	0.0	0.0	3.74	70.3	.1
23	0.0	814.2	523	.3	.040	0.0	0.0	32.57	20.9	.0

CYCLE COMPOSITE			
	HC	14.497	GRAM/BHP HR
	CO	326.163	GRAM/BHP HR
	NO2	2.368	GRAM/BHP HR
	ALDE	0.000	GRAM/BHP HR
	BSFC	.814	LB/BHP HR

APPENDIX H

STATES INCLUDED IN NORTHERN, CENTRAL AND SOUTHERN REGIONS FOR THE PURPOSE OF REGIONAL MASS EMISSIONS ANALYSIS

THREE REGIONS OF THE U. S. AS DEFINED FOR REGIONAL EMISSIONS ANALYSIS

Northern Region	Central Region	Southern Region
Idaho	Colorado	Alabama
Maine	Connecticut	Arizona
Minnesota	Delaware	Arkansas
Montana	Dist. of Columbia	California
New Hampshire	Illinois	Florida
North Dakota	Indiana	Georgia
Oregon	Iowa	Louisiana
South Dakota	Kansas	Mississippi
Vermont	Kentucky	New Mexico
Washington	Maryland	North Carolina
Wisconsin	Massachusetts	Oklahoma
Wyoming	Michigan	South Carolina
	Missouri	Tennessee
	Nebraska	Texas
	Nevada	
	New Jersey	
	New York	
	Ohio	
	Pennsylvania	
	Rhode Island	
	Utah	
	Virginia	
	West Virginia	

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. APTD-1494	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Exhaust Emissions From Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines - Final Report, Part 5 - Heavy-Duty Farm, Construction, and Industrial Engines		5. REPORT DATE October 1973
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Charles T. Hare and Karl J. Springer		8. PERFORMING ORGANIZATION REPORT NO. AR 898
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16. ABSTRACT

This report is part 5 of the Final Report on Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines. The engine categories covered in this report are heavy-duty gasoline and diesel engines used in farm, construction, and industrial applications. The report includes descriptions and photographs of the test engines, instrumentation systems used, explanations of test sequences and calculation methods employed. The engines were tested using well-accepted steady-state procedures for gaseous emissions measurement, and in addition, the Federal procedure for smoke certification was used for testing the diesel engines (except the Onan). Some gaseous emissions were measured during transient operation of most of the engines, and particulate and smoke measurements were made during some of the same modes used for gaseous emissions sampling. The emissions results obtained in this study, as well as data obtained from other sources, were used in conjunction with information on engine population and usage to estimate emission factors. National impact was estimated separately for each of three engine applications. The categories of engines covered in this report appear to make some significant, but not major, contributions to national pollutant totals from man-made sources.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Smoke	Carbon monoxide	Particulates	13B
Oxygen	Carbon dioxide	Emission factors	
Aldehydes	Total hydrocarbons	Federal smoke tests	
Diesel engines	Nitrogen oxides	Federal 13 mode test	
Air pollution	Light hydrocarbons	National emissions impact	
Gasoline engines	Chemical analysis	EMA-California ARB 13 mode procedure	
Exhaust emissions	Agriculture machinery		
	Construction equipment		

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