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Heavy-Duty Diesel Emissions as a Function of Alternate Fuels

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Heavy-Duty Diesel Emissions as a Function of Alternate Fuels

by

Terry L. Ullman and Charles T. Hare

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas 78284

Contract No. 68-03-2884
Task Specification 14

EPA Project Officer: Robert J. Garbe
Branch Technical Representative: Thomas M. Baines

Prepared for

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FOREWORD

The project on which this report is based was initiated by Task Specification No. 14 of EPA Contract 68-03-2884, received by SwRI on October 19, 1981. The contract was for "Basic Characterization Support for the Emission Control Technology Division." Task Specification No. 14 of that Contract was specifically for "Heavy-Duty Diesel Emissions as a Function of Alternate Fuels." The work was identified within SwRI as Project No. 11-5830-014.

The Project Officer and the Branch Technical Representative for EPA's Technology Assessment Branch during the Task Specification were Mr. Robert J. Garbe and Mr. Thomas M. Baines, respectively. SwRI Project Director was Mr. Karl J. Springer, and SwRI Project Manager was Mr. Charles T. Hare. The SwRI Task Leader and principal investigator for the Task Specification No. 14 effort was Mr. Terry L. Ullman. Lead technical personnel were Mr. Patrick Medola and Mr. Gregory W. Boyd.

We would like to express our appreciation to Mack Trucks, Inc., for supplying the model EM6-300 test engine for this work. We also appreciate the assistance of A.E. Staley Co. in supplying the soybean oil used as one of the test fuels, and the cooperation of the Coca-Cola Bottling Co. of San Antonio in providing the project with used lubricating oil to act as a fuel blend component.

ABSTRACT

Laboratory emissions evaluations were performed on a heavy-duty diesel engine in this program, using a total of five different fuels and fuel blends. The work was all done with a Mack EM6-300 turbocharged and intercooled engine mounted on a transient-capable dynamometer. Operating procedures used included both the 1984 transient FTP[(1)*] and 1986 proposed transient FTP[(2)], and variations of the 1979 13-mode steady state.[(3)] The base petroleum-derived fuel was phillips D-2 Control fuel; it was also used as blend stock with Solvent Refined Coal-II (SRC-II) and Exxon Donor Solvent (EDS) middle distillates, and with used lubricating oil, to form three of the test fuels. The remaining test fuel was "once refined" soybean oil (A.E. Staley Co.), run without blending, but heated to 145°C to reduce its viscosity.

Emissions measurements included gaseous and particulate components, using both direct-stream and dilute sampling for gases, and dilute sampling (only) for particulate matter. Regulated pollutants measured were total hydrocarbons, carbon monoxide, oxides of nitrogen, carbon dioxide (as necessary for fuel consumption calculations), visible smoke, and total particulate mass. Unregulated pollutants measured included aldehydes, phenols, some individual (low molecular weight) hydrocarbons, and odor index (DOAS) in exhaust gases. Analysis of particulate matter included sulfate, elemental composition, size distribution, and total organic soluble mass. The solubles were further analyzed by determining boiling range, BaP, Ames bioassay, and HPLC fractionation. Methods used for measurements and analyses were mostly developed during the course of previous EPA Contracts No. 68-03-1230,[(4)] 68-02-1777,[(5)] 68-02-2497,[(6)] 68-03-2706,[(7)] and (previously completed) Task Specifications No. 3 and No. 6 of the subject Contract.[(8,9)]

Relative to the baseline fuel, the EDS, SRC-II, and lube oil blends had little effect on currently-regulated gaseous emissions (HC, CO and NO_x) or on BSFC. Similarly, little change was noted for total particulate emissions, although sulfate emissions were higher as a result of the higher fuel sulfur contained in the SRC-II and lube oil blends. The soluble organic portion of the total particulate was about the same level with these alternate fuel blends as for the baseline D2 fuel. The level of benzo(a)pyrene emissions for the EDS, SRC-II and lube oil blends was greater than for the baseline fuel. The Ames response was somewhat higher for the EDS and SRC-II blends. Substantial quantities of metals were found in the particulate with the used lubricating oil blend. Gaseous emissions of HC, CO and NO_x were lower with the use of heated soybean oil. The BSFC was substantially increased, as was the total particulate (which was mostly unburned soybean oil-like material), especially during light loads. The soluble organic fraction of the total particulate contained much higher levels of BaP, but the Ames response was considerably lower than for the baseline fuel when neat soybean oil was used.

*Superscript numbers in parentheses designate references at the end of this report.

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I. INTRODUCTION

The long-term petroleum supply outlook makes it prudent to characterize the emissions from combustion of all important alternative fuel and fuel extender concepts. Among the many effects these concepts may have on transportation and utility engines, their differing compositions are likely to produce changes in exhaust emissions. These potential changes are the reason for the research program reported here.

Other Task Specifications of the subject Contract have generated experimental data on alcohol fuels in a heavy-duty direct-injection engine with diesel fuel pilot-ignition,[9] and on alternative-source fuels and fuel blends in a light-duty diesel vehicle;[8] and one Work Assignment of another Contract has resulted in information on methanol combustion in a direct-injection spark-ignited heavy-duty engine.[10] These previous efforts have not, however, covered alternate-source fuel blends, used lubricating oil blends, or vegetable oils as fuels for heavy-duty diesel engines. This work has been done to fill this information gap, providing data on the emissions effects of several fuel or fuel extender options either in use or under active consideration.

This project covers use of a widely-produced vegetable oil (soybean oil), a blend of 5 percent used lubricating oil in a base petroleum fuel, and blends of two different coal-derived middle distillates at 25 percent in the base fuel. The engine used was a modern 4-stroke cycle truck diesel, operated without modification or adjustment on all the fuels (the soybean oil was run at elevated fuel temperature, however). The test work was generally of short duration, so long-term effects of the fuels on deposits or wear could not be evaluated. Compared to the operation of small research engines or even light-duty vehicles, tests of large (typical) heavy-duty engines require more fuel. This factor is important when evaluations of alternate-source materials are being conducted, because most of the fuels require careful blending and analysis, both of which are time-consuming and expensive.

We are fortunate that test fuels and components could be made available for this project with very little cost other than measuring their properties and negotiating for their acquisition. It will be useful to follow up this initial screening, however, with further evaluations when additional alternative fuels are developed. The coal-derived liquids used in this work did not represent consumer-ready products, and no suitable liquids from oil shale or tar sands processing were available.

II. SUMMARY

Emissions from a Mack EM6-300 heavy-duty diesel engine were characterized over steady-state and transient operation with five different fuels. The baseline fuel was a DF-2 emissions "control" fuel made by Phillips Petroleum Co. The other fuels tested in this program were a blend of 25% Exxon Donor Solvent (EDS) distillate with 75 percent baseline fuel, a blend of 25 percent Solvent Refined Coal-II (SRC-II) distillate with 75 percent baseline fuel, a blend of 5 percent filtered, used lubricating oil with 95 percent baseline fuel, and neat soybean oil (at 145±6°C). No changes to the engine or fuel system were made in order to optimize the usage of any of the test fuels. Regulated emissions as well as several unregulated exhaust emissions were measured in order to determine the relative impact of the alternate fuels on exhaust emissions. Table 1 summarizes the composite values of emissions measured over the 1979 13-mode steady-state FTP (or 11 modes, where the idle was only run once) and the 1984 Transient FTP using each of the five test fuels. Detailed test results may be found in the "Results" section of this report (Section IV).

Regulated emissions results obtained with the baseline fuel over steady-state and transient testing were quite similar, although the emissions of HC, CO, and NO_x were slightly higher for transient testing. The BSFC for the transient test procedure was 13 percent higher than for the steady-state 13-mode test procedure. Both 13-mode and transient HC, CO, and NO_x emissions obtained with the baseline fuel, as well as with the alternate fuels, were below the level of the 1984 emission standards for heavy-duty diesel engines (assuming that the 13-mode HC emission standard is revised from 0.5 to 1.0 g/bhp-hr for 1984). Some individual hydrocarbons (low molecular weight hydrocarbons), aldehydes, and phenols were measured, and were generally low with the baseline fuel. In addition to these unregulated emissions, total particulate emissions were also determined over steady-state and transient testing. The particulate emission level on baseline fuel over the Transient FTP (0.59 g/bhp-hr) was substantially greater than the proposed 1986 emission standard of 0.25 g/bhp-hr, but it was representative of most conventional heavy-duty diesel engines. Total particulate emitted during transient operation was analyzed for sulfate, and the soluble organic fraction (SOF) was also determined. The SOF was analyzed for benzo(a)pyrene (BaP), and for relative bioactivity by the Ames test. In addition, the boiling point distribution and the presence of polar, transitional, and non-polar compounds in the SOF were determined.

With the EDS fuel blend compared to base fuel, no significant difference was noted for either HC or CO emissions under either steady-state or transient operation. Emissions of NO_x increased by 12 and 9.4 percent over steady-state and transient testing with the EDS blend, respectively. No change in BSFC was noted from baseline values. Slight increases in individual hydrocarbon and aldehyde levels were noted with the EDS blend. An increase in phenols with this alternate fuel was due to an increase in phenols over the hot-start

TABLE 1. SUMMARY OF COMPOSITE EMISSIONS FROM THE MACK EM6-300 ON BASELINE AND ALTERNATE FUELS

Fuel	Emissions by Fuel and Test Procedure									
	Baseline Phillips 2D		25% EDS + Phillips 2D		25% SRC-II + Phillips 2D		5% Lube Oil + Phillips 2D		100% Soybean Oil @ 145°C	
Federal Test Procedure (FTP)	13-Mode	Transient	13-Mode	Transient	13-Mode	Transient	13-Mode	Transient	13-Mode	Transient
Hydrocarbons, HC g/kW-hr, (g/hp-hr)	0.85 (0.63)	0.90 (0.67)	0.84 (0.63)	0.88 (0.66)	0.91 (0.68)	0.84 (0.62)	1.04 (0.78)	0.98 (0.73)	0.43 (0.32)	0.49 (0.37)
Carbon Monoxide, CO g/kW-hr, (g/hp-hr)	3.25 (2.42)	4.45 (3.32)	2.93 (2.19)	4.35 (3.24)	3.44 (2.56)	4.91 (3.66)	2.68 (2.00)	4.29 (3.20)	2.64 (1.97)	4.04 (3.01)
Oxides of Nitrogen, NO_x[b] g/kW-hr, (g/hp-hr)	10.05 (7.50)	10.18 (7.59)	11.27 (8.40)	11.14 (8.31)	11.33 (8.45)	12.31 (9.18)	10.33 (7.71)	10.74 (8.01)	9.21 (6.87)	7.82 (5.84)
Brake Specific Fuel Consumption kg fuel/kW-hr, (lb/hp-hr)	0.233 (0.383)	0.263 (0.432)	0.234 (0.385)	0.262 (0.431)	0.235 (0.386)	0.266 (0.438)	0.232 (0.381)	0.264 (0.434)	0.275 (0.452)	0.301 (0.494)
Unregulated Emissions										
Total Individual HC mg/kW-hr	--	76	--	82	--	50	--	58	--	170
Total Adlehydes mg/kW-hr	--	7.5	--	11	--	6.1	--	6.0	--	9.0
Total Phenols mg/kW-hr	--	2.2	--	9.0	--	7.6	--	4.8	--	4.5
Total Particulate[a] g/kW-hr, (g/hp-hr)	0.63[a] (0.47)	0.79 (0.59)	0.62[a] (0.46)	0.70 (0.53)	0.60[a] (0.45)	0.67 (0.50)	0.71[a] (0.53)	0.83 (0.63)	0.56[a] (0.42)	0.93 (0.73)
Sulfate, $SO_4^{=}$ mg/kW-hr, (% of Particulate)	--	37 (4.7%)	--	27 (3.9%)	--	49 (7.3%)	--	54 (7.0%)	--	0 (0%)
Soluble Organic Fraction (SOF) mg/kW-hr, (% of Particulate)	140[a] (22%)	130 (16%)	150[a] (24%)	140 (19%)	140[a] (23%)	150 (22%)	140[a] (20%)	130 (16%)	270[a] (48%)	570 (59%)
BaP µg/kW-hr	--	0.12	--	0.61	--	0.49	--	0.33	--	4.7
Ames Response[c] (10^3 rev./plate)/kW-hr	--	80	--	100	--	87	--	77	--	22

[a]Based on 11-modes (idle run once)
[b]Based on continuous measurement. Bag measurement also taken.
[c]Average of brake specific response with and without metabolic activation from all 5 strains

transient test. Although no difference in the level of total particulate emissions was noted for steady-state testing, total particulate decreased by 11 percent over transient operation with the EDS blend. A 27 percent reduction in sulfate emissions was likely due to the 21 percent lower fuel sulfur content of the EDS fuel blend. There was very little difference in the relative portion of soluble organic fraction present in particulate from operation with the EDS blend; but the BaP emission level was 5 times that with the baseline fuel, and the Ames response was notably higher.

A blend of 25 percent SRC-II with 75 percent baseline D2 fuel resulted in no significant change for either HC or CO emissions. Using this higher nitrogen content SRC-II fuel blend, emissions of NO_x over the steady-state and transient testing increased by 13 and 21 percent, respectively. Although the BSFC over both test procedures appeared to increase slightly, the change was within the range of test-to-test variability. Individual hydrocarbons and aldehydes were generally reduced, but phenol emissions were greater than those obtained with the baseline fuel. Total particulate was 4.8 and 15 percent less than obtained over steady-state and transient testing with the baseline fuel, respectively. Although total particulate decreased with the SRC-II fuel blend, the sulfate increased by 32 percent, likely due to the 17 percent higher sulfur content of this alternate fuel blend. Very little change was noted in the amount of SOF in particulate. The BaP emission level was about 4 times that obtained with the baseline fuel. The Ames response was slightly greater than that obtained with base fuel.

With a blend of 5 percent filtered lubricating oil and 95 percent baseline fuel, the HC emissions increased by 23 percent, and the CO emissions decreased by 17 percent for the 13-mode steady-state testing. Although these same trends appeared over transient testing, the minimal changes in HC and CO emissions noted were within the range of test-to-test variability. Both test procedures indicated a trend toward higher NO_x emission with the lube oil blend, but the slightly higher values were within the range of test-to-test variability. No change in BSFC was noted. Levels of individual hydrocarbons and aldheydes were slightly below, while phenols were above, the levels obtained with the baseline fuel. Although a 13 percent increase in particulate over the modal test procedure occurred, only an insignificant increase in particulate over the transient test cycle was noted. Sulfate was 46 percent higher with the lube oil blend, despite little difference in the amount of sulfur contained in the fuel blend (0.23 for baseline vs. 0.24 wt.% for lube oil blend). In addition to more sulfate, elemental analysis of the total particulate indicated substantial quantities of metals and other lube oil-related elements in the particulate. The SOF emissions were the same as obtained for the baseline fuel, but the BaP level doubled, and the Ames response was essentially the same as found for the base fuel.

The engine was also tested with neat soybean oil, heated to 145°C in order to achieve a viscosity similar to that of the baseline diesel fuel. Although the engine operated well on this heated fuel, the maximum power obtained without adjusting the fuel injection system was reduced by 20 percent. Brake specific HC emissions dropped by an average of 47 percent over both steady-state and transient testing. This reduction in HC emission was somewhat surprising, and was likely due to the relatively high boiling point of the neat soybean oil. Much of the unburned or partially oxidized fuel probably did not reach the heated flame ionization detector, because the heated sampling train (190°C) for HC includes two heated filters which could have collected the unburned soybean oil as particulate. The emission of CO decreased by 19 and 9 percent over the 13-mode and transient test procedures, respectively. Decreases of 8 and 23 percent were noted for NO_x emissions over the 13-mode and transient test procedures with the neat soybean oil, respectively. Most of this reduction may have been due to a longer ignition delay which effectively retarded the timing. The BSFC increased by 18 and 14 percent over the 13-mode and transient test procedures. Individual hydrocarbons were substantially higher, mostly the emissions of ethylene, propylene and benzene. Aldehydes were only slightly higher than obtained with the baseline fuel. Although the phenol emissions were almost doubled compared to those obtained with the baseline fuel, the level was still very low.

Total particulate for the 13-mode test procedure was 11 percent lower with soybean oil than with the baseline fuel, due to reductions in total particulate during heavy load conditions which more than offset increased particulate emitted during light load conditions. Full load smoke opacity was reduced by about one-third, but higher smoke opacities were noted for light load conditions. The total particulate for the transient test procedure was 24 percent higher with the soybean oil than with the baseline fuel, due to higher total particulate emissions for the light load conditions which are prevalent in the transient engine exercise. No sulfate was detected, since the neat soybean oil contained no sulfur. Likewise, no metals or similar contaminants were found in quantity from elemental analysis of the total particulate. The soluble organic fraction of the total particulate was relatively high for both steady-state and transient operation with soybean oil. Most of the SOF was found at the light loads, which is typical, but substantial quantities were also noted during the relatively high load conditions, particularly during rated speed operation. This SOF made up 59 percent of the total particulate collected over the transient test procedure. The boiling point distribution of the SOF and that of the soybean oil were similar, which, along with the relatively high hydrogen-to-carbon ratio of the total particulate, indicates that the SOF was unburned or partially oxidized soybean oil. Emissions of BaP were 39 times those obtained with the baseline fuel. The brake specific Ames response was very low, relative to the levels obtained with the base fuel or the EDS blend, despite the relatively high BaP levels indicated.

This work has shown that alternate fuel blends may be used to extend the supply of diesel fuel by using EDS middle distillates, SRC-II, or filtered, used lubricating oil. For the Mack EM6-300, these fuel extenders were used without penalty to BSFC or significant increase in currently-regulated gaseous emissions. The test engine also operated well on neat, heated soybean oil, confirming the wide range of hydrocarbons which can be utilized for "diesel fuel." Although neat soybean oil could be provided as an alternate fuel, increased BSFC and the significant increases in total particulate (mostly unburned fuel species) would result, at least in the absence of compensating injection system changes or adjustments which were beyond the scope of this effort.

III. TEST PLAN AND DESCRIPTION OF ENGINE, FUEL AND PROCEDURES

The intent of this program was to characterize regulated gaseous emissions along with particulate and unregulated emissions from a Mack EM6-300 operated on baseline Phillips D-2 Control fuel, 25 percent EDS with 75 percent baseline fuel, 25 percent SRC-II with 75 percent baseline fuel, 5 percent lube oil with 95 percent baseline fuel, and neat soybean oil heated to 145°C. This section describes the test plan used in the program. Some of the pertinent engine specifications will be presented. Properties for the fuel blends and the neat soybean oil will also be given. Procedures are described, including both the test procedures used to generate and acquire emission samples and the analytical procedures used to characterize the emission samples.

A. Test Plan

The planned program included emission measurements of both regulated and unregulated emissions for the engine in an "as-received" condition with the baseline test fuel. The engine was tested over both steady-state and transient operation. Table 2 illustrates the extent of emissions characterization performed on each of the five test fuels.

B. Description of Test Engine

Figures 1 and 2 show the Mack EM6-300 engine mounted as operated on a transient-capable dynamometer. The EM6-300 is marketed as a "high efficiency" heavy-duty diesel engine. A portion of the improved efficiency over previous models is derived from the use of a charge-air intercooler. This intercooler resembles a radiator, and is normally mounted in front of the engine water coolant radiator in a truck installation. For test purposes, Mack has developed a test cell version of this intercooler using cooling water so that fan power does not enter in as a test variable. This test cell intercooler is shown beside the engine in Figure 1.

The test engine was of a six cylinder in-line configuration with direct injection, turbocharged and intercooled, and it developed 230 kW (308 hp) at a rated speed of 2100 rpm with maximum fuel flow of 53.1 kg fuel/hr (117 lb fuel/hr) on the baseline fuel (Phillips D-2). The engine developed 1504 N•m (1109 ft-lb) of torque at an intermediate speed of 1260 rpm with fuel flow of 41.8 kg fuel/hr (92 lb fuel/hr). The engine utilized an air operated (90 psi) aneroid valve to reduce smoke emissions during rapid "throttle" movements to higher power.

C. Test Fuel Acquisition, Blending, and Properties

Fuel used in this project included a base No. 2 petroleum diesel fuel, a soybean oil, and base fuel mixtures with two different coal-derived distillates and a used lubricating oil. Criteria for selection of the base and alternate-source fuels and blending components, as well as the used oil "fuel extender," are given in this section.

TABLE 2. PLANNED EMISSION MEASUREMENTS FOR CHARACTERIZATION OF THE MACK EM6-300 OPERATED ON EACH TEST FUEL

Exhaust Constituents(s) Measured or Characterized	Test Sequences: Transients, Cold 1	Transients, Cold 2	Transients, Hot 1	Transients, Hot 2	13-Mode 1	13-Mode 2	(Full) Power Curve
Visible Smoke, PHS[a]					✓		✓
Regulated Gaseous Emissions	✓	✓	✓	✓	✓	✓	
Individual Hydrocarbons	✓		✓				
Aldehydes	✓		✓				
Phenols	✓		✓				
Odor Index, DOAS	✓		✓				
Particulate Characterization							
Mass	✓	✓	✓	✓	✓[b]	✓[b]	
Size Distribution	✓		✓				
C and H	✓		✓				
Metal Content	✓		✓				
Sulfate	✓		✓				
Characterization of Solubles in Particulate							
Mass	✓	✓	✓	✓	✓[b]		
Boiling Range	✓		✓				
BaP	✓		✓				
Ames Bioassay	------	✓	---[c]---				
HPLC Fractionation[d]	✓		✓				

[a] Run Federal smoke also, if testing performed on capablè dynamometer
[b] Determined for 11 modes (idle only run once)
[c] One composite sample for transient
[d] Qualitative determination of aromatic, transitional, and oxygenated fractions

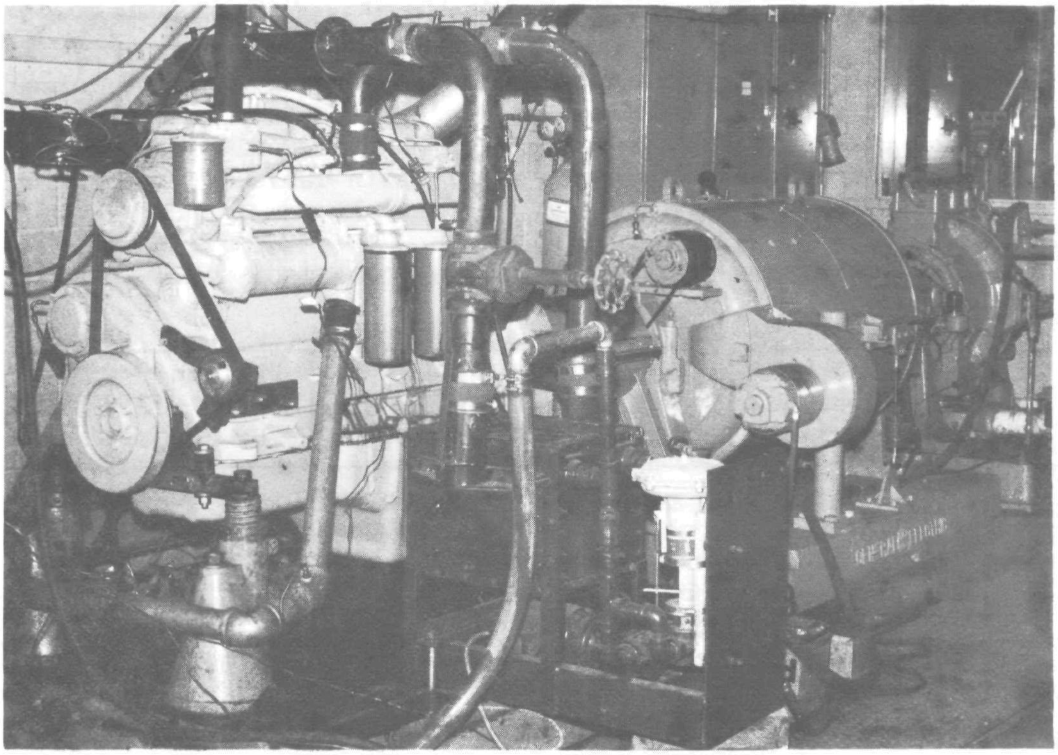

Figure 1. Front view of Mack EM6-300 with "test cell" intercooler

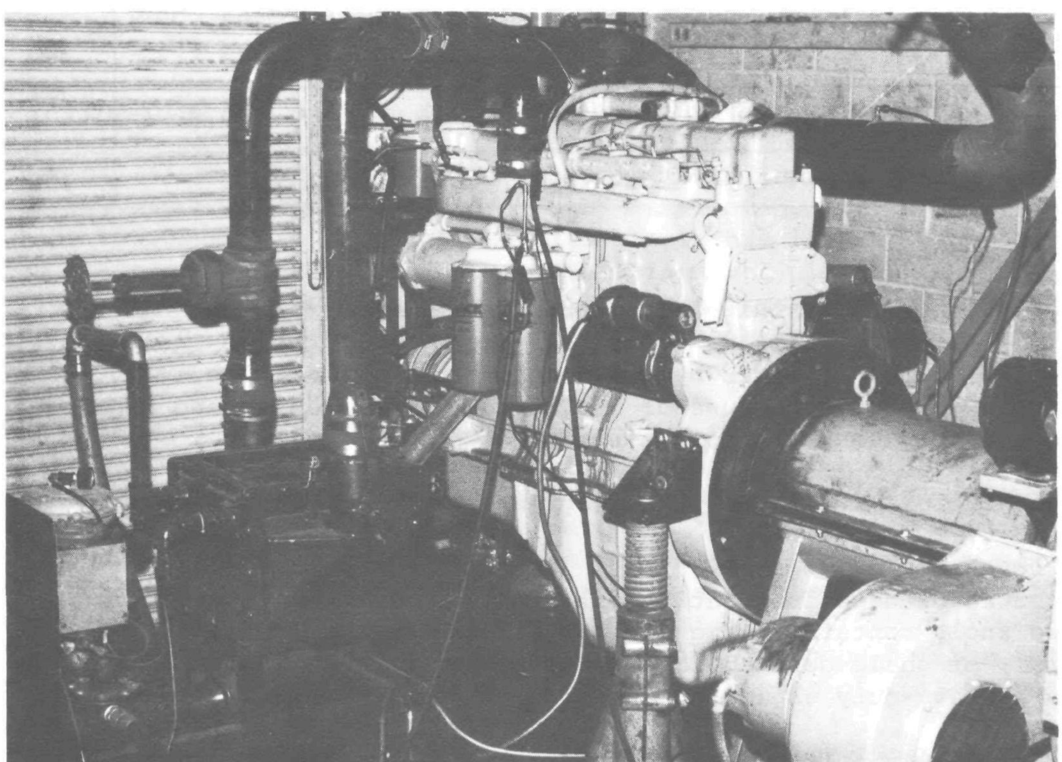

Figure 2. Mack EM6-300 mounted for emissions test work

1. Selection of Fuels and Blending Components

The base fuel chosen for this Task Specification was Phillips "Diesel Control Fuel D-2," and it was obtained from Phillip's Lot C-504. The Task Technical Officer made this selection from fuels on hand at SwRI based on a comparison of properties from various sources as given in Table 3. Properties

TABLE 3. CANDIDATE BASE FUEL PROPERTY COMPARISON

Fuel	DOE 1981 Average 2D(11)	2D Emissions	Local Gulf 2D	Phillips Control D2, Lot C-504	Old Base 2D
Fuel Code	--	EM-487-F	EM-409-F	EM-498-F, EM-509-F	EM-329-F
Gravity, °API	34.9	35.9	39.6	35.7	37.5
Viscosity, cS	2.72	2.49	2.30	2.44	2.36
Sulfur, wt. %	0.28	0.26	0.23	0.25	0.24
Cetane Number (D613)	45.6	no data	no data	46.3	50
Cetane Index (D976-80)	45.6	45.3	50.7	46.2	49.9
IBP, °C	192	179	176	200	191
10% point, °C	222	214	201	224	219
50% point, °C	261	252	248	257	260
90% point, °C	308	299	311	296	307
EP, °C	335	333	344	323	340
Aromatics, %	no data	32.8	22.0	29.8	21.3
Supply on hand, gal	--	5500	1700	600	300

of the Phillips fuel given in this table were from Phillips' batch analysis. Both fuel EM-487-F and the Phillips Control D2 are quite close to the properties of the average 1981 D2 as reported by DOE's most recent national summary.(11) The Phillips fuel was chosen because of its current availability and widespread use, providing possibly the best comparability to other studies.

The other test fuels for this program were planned as follows:

- a vegetable oil
- a blend of used lubricating oil with base fuel
- two fuels containing the maximum practical amounts of coal- or shale-derived components not already evaluated in a heavy-duty engine.

Consultation with other research personnel at the Intitute about vegetable oils was conducted, following up on work already published.[12,13,14,15,16,17] Oils considered for use included:

- sunflower oil
- soybean oil
- peanut oil
- transesterified cottonseed oil
- used (generic) frying oil

It was decided that the used frying oil posed too many problems for use, primarily due to potential animal fat content. The transesterified cottonseed oil was a strong candidate, since its properties were more like a diesel fuel's than the other oils'; but the economics and potential acceptability of the transesterification process were not considered well enough known to justify using our experimental effort on it at this time. Although the overall energy balance for production of sunflower oil may be better in some locations, soybean oil was chosen for this project because it is currently produced in larger amounts and in more areas of the country than the other oils.

Soybean oil is available in bulk with several degrees of processing. These products are known as "crude," "degummed," "once refined," and "hydrotreated" soybean oils. The material chosen for this program was once refined soybean oil, made available on a gratis basis by A.E. Staley Company. Although this oil can be used in a diesel engine without modifications, it reportedly tends to cause accumulation of gummy deposits, leading to engine damage after relatively short periods. It has been found that heating the oil to reduce its viscosity and improve its spray pattern is beneficial,[13] so it was decided to heat the oil to 145°C at the fuel pump.

Regarding the mixture of used lubricating oil with diesel fuel, interest in this material as a fuel stems from a practice followed by some diesel vehicle fleets for both fuel economy and oil disposal purposes.[18,19,20] The most commonly used concentration of used lubricating oil in fuel seems to be about 5% by volume, so it was decided to adopt this level for our work. Oil selection criteria included use (normal drain interval mileage) in long-haul diesel fleet operation, availability of oil type and usage history information, and relative freedom from contamination by water, ethylene gylcol, and other substances.

At the time this project was conducted, the only coal-derived products available for testing were SRC-II and EDS middle distillates, and EDS naphtha. The only oil shale product available was Paraho diesel fuel-marine. The two coal-derived middle distillates were chosen as blending components for this work because the naphtha would be used more logically as a gasoline blending component, and because the shale fuel was a specification-quality product not expected to produce emissions substantially different from those produced on base fuel.[8,21] The 25% blending level chosen for the two coal-derived products was based on experience in another phase of this Contract.[8]

Properties of the used lubricating oil and the coal liquids used as blending components are given in Table 4, not to be confused with properties of the final fuel blends. Additional information on the used oil (EM-512-A) was obtained by infrared spectroscopy, and this analysis showed a trace of water or ethylene glycol, normal zinc-containing (ZDDP) and sulfonate additives, and little or no oxidation or nitration. The x-ray analysis indicated small amounts of phosphorus, chlorine, and iron, plus a trace of lead, in addition to the sulfur and metals shown in Table 4.

The coal liquids from the SRC-II (EM-472-F) and EDS (EM-480-F) processes are highly aromatic, quite dense, contain a lot of gum, and have low cetane numbers. The SRC-II distillate also has substantial oxygen content, and the EDS distillate has heavy ends which can not be quantified by ASTM D86 distillation. Both coal liquids are considered hazardous to handle, they have strong odors, and they are very dark in color. They are currently considered as only a first attempt to make combustible liquids from coal, and not to be products ready for consumer use.

2. Detailed Properties of Test Fuels

Properties of the base fuel and the four alternate or blended fuels are given in Table 5. Almost all these data are from analysis conducted at SwRI, and a few entries for the base fuel differ slightly from the Phillips data given in Table 3 with the discussion of the fuel selection criteria. Starting with cetane numbers, the fuel with the poorest probable ignition quality appears to be 25% SRC-II in base fuel, EM-511-F. This blend indicates that the SRC-II depresses cetane more than would be expected from linear interpolation between the cetane numbers of the components. The same trend also holds for the EDS blend (EM-515-F), but to a much lesser extent. The 5% lubricating oil blended into EM-517-F affected cetane number only slightly. The soybean oil's cetane number at standard D613 test conditions (fuel temperature 38°C) was just under 40, and it apparently went up about 3 points with elevated fuel temperature of 145°C. This modest change may have resulted from differences in spray geometry caused by viscosity decrease, from shortening of ignition delay,[23] or a combination of these and other factors. In either case, however, the soybean oil did have ignition quality sufficiently good to be used (for brief periods at least) as a fuel in a diesel engine.

Densities of all the fuels were measured using standard hydrometers at 60°F (16°C), indicating that all four test fuels were more dense than the base fuel. For the three blends, densities were as expected based on components used. For the soybean oil, density was approximately 9% greater than base fuel when measured at equal temperatures. When projected linearly to the temperature (145°C) at which the soybean oil was actually tested, using density data from the literature,[13] its density decreased to 0.839 g/mℓ. This value is about equal to the base fuel's expected density at normal fuel temperatures.

Viscosities of the test fuel blends are in the expected ranges given their constituents, but the values for the coal liquid blends are in the inverse

TABLE 4. PROPERTIES OF THREE FUEL BLENDING COMPONENTS

Material Description	Used Lubricating Oil, 10w-40	SRC-II Middle Distillate from Coal	EDS Middle Distillate from Coal
Material Code	EM-512-A	EM-472-F	EM-480-F
Gravity, °API	26.1	14.3	18.6
Density, g/mℓ	0.898	0.970	0.943
Viscosity, cS	177. @ 40°C 17.6 @ 100°C	3.68 @ 38°C	3.30 @ 38°C
Cetane No., D613	---[a]	16	23
Distillation, D86, °C-IBP	---	178	209
5%	---	192	220
10%	---	202	223
20%	---	211	231
30%	---	217	237
40%	---	224	247
50%	---	230	260
60%	---	236	274
70%	---	244	291
80%	---	252	311
90%	---	261	348
95%	---	270	not reached
EP	---	297	not reached
recovery, %	---	99.0	94.0
Gum, mg/100 mℓ	---	156.9	228.6
Carbon, %	---	86.2	88.6
Hydrogen, %	---	8.6	10.7
Nitrogen, %	---	0.83	0.08
Oxygen, %	---	3.9	not detected
Sulfur, %	0.44	0.27	0.01
Metals (x-ray)	0.13%Zn, 0.04%Ca	---	---
Aromatics, %	---	88.3	83.7
Olefins, %	---	0.6	0.0
Paraffins, %	---	11.0	16.3
Total Acid No., mg/g	4.07	---	---
Total Base No., mg/g	3.51	---	---

[a]not measured

TABLE 5. PROPERTIES OF TEST FUELS USED IN MACK EM6-300

Fuel	(Base) Phillips D2 "Control," Lot C-504	Staley "Once-Refined" Soybean Oil	25% SRC-II Middle Dist. in Base	25% EDS Middle Dist. in Base	5% Used Lubricating Oil in Base
Fuel Code	EM-509-F	EM-510-F	EM-511-F	EM-515-F	EM-517-F
Cetane Number (D613)	48.9	39.3	34.0	40.6	48.0
Cetane Number @ 145°C	---[a]	42.9	---	---	---
Cetane Index (D976-80)	46.5	---	34.9	37.4	46.2
Gravity, °API @ 16°C	35.6	21.7	29.8	29.9	35.2
Density, g/mℓ @ 16°C	0.847	0.924	0.877	0.877	0.849
Viscosity, cS @ 40°C	2.38	30.6	2.44	2.56	2.77
Viscosity, cS @ 145°C	---	2.71[b]	---	---	---
Gum, mg/100 mℓ (D481)	0.6	---	51.4	39.2	1513.3
Total Solids, mg/ℓ (D2276)	5.9	approx. 10	38.1	19.6	880.
Flash Point, °C	75	320	---	---	---
Cloud Point, °C (D2500)	-17	-1	---	---	---
Aromatics, vol.%	31.0	---	44.5	42.4	---
Olefins, vol.% (D1319)	1.2	---	1.4	0	---
Paraffins, vol.% (balance)	67.8	---	54.1	57.6	---
Carbon, wt. %	87.7	77.6	86.5	87.4	86.7
Hydrogen, wt. %	12.9	11.5	12.0	12.4	13.0
Oxygen, wt. %	0.06	9.90	1.23	0.24	0.15
Nitrogen, ppm (oxid. pyrol.)	80	not detected	2200	270	110
Sulfur, wt.% (D1266-70)	0.23	not detected	0.27	0.18	0.24
Iron, ppm	16	11	58	13	14
Zinc, wt. %	---	---	---	---	0.07
Distillation, °C(D86)-IBP	192	---	187	206	201
10%	222	---	211	224	223
20%	233	---	222	232	235
30%	242	---	232	241	244
40%	252	---	241	250	252
50%	259	---	249	258	261
60%	267	---	258	267	269
70%	276	---	267	276	278
80%	285	---	277	287	289
90%	298	---	293	303	308
95%	311	---	303	319	327
EP	327	---	318	351	327
residue, %	1.0(loss 0)	---	1.1(loss 0.9)	1.5(loss 0.5)	3.0(loss 0)
Distillation, °C (2887) -IBP	114	361	120	124	126
5%	193	539	188	198	193
10%	209	563	203	211	211
20%	232	586	222	231	228
30%	248	594	239	247	241
40%	260	600	252	260	254
50%	272	606	263	272	266
60%	282	610	274	284	278
70%	293	614	285	296	292
80%	305	620	298	308	309
90%	320	627	314	325	332
95%	332	644	327	341	360
EP	364	681	367	410	555

[a] analysis not performed due to inapplicability or lack of usefulness
[b] projected by least squares from data taken at 20, 40, and 100°C

of their expected rank order. The neat SRC-II middle distillate had higher viscosity than the EDS, but its blend with the base fuel had lower viscosity than the EDS blend. The 5% lubricating oil blend showed a higher viscosity than either coal liquid blend. Soybean oil (EM-510-F) had much higher viscosity at 40°C than the other fuels, but heating it to 145°C brought its viscosity into the normal No. 2 diesel fuel range. The high-temperature viscosity value was projected from data at 20, 40, and 100°C via a logarithmic equation relating temperature and viscosity.

Data on gum content of test fuels, as determined by ASTM D381, show a wide variation between near-zero and something over 1500 mg per 100 mℓ. The procedure used was designed for gasolines and jet fuels, and its importance in this study is questionable. It is supposed to determine residues after fuel evaporation by a steam jet at 232 to 246°C, but some components of the test fuel blends used in this project may not be properly classified as gum even though they did not evaporate under the specified analysis conditions.

Analysis for hydrocarbon type composition was attempted on the lubricating oil mix (EM-517-F), but fluorescence zones were not discernible due to the sample's extremely dark color. It is quite certain, however, that the oil blend has paraffins a bit higher and aromatics a little lower than base fuel. The FIA analysis was not attempted for the soybean oil (EM-510-F) because it is not applicable.

Soybean oil consists mostly of triglycerides of oleic, linoleic, and linolenic fatty acids (23.6%, 56.7%, and 4.2% by weight, respectively, for our material). Saturated acids are usually about 14% in soybean oil and free fatty acids under 1%. In essence, then, the soybean oil is made up mostly of eighteen-carbon chains having from zero to three double bonds, attached to gylcerin molecules in groups of three with six oxygen atoms per molecule. If the soybean oil consisted entirely of triglycerides of linoleic acid (the most abundant fatty acid), it would have a simplified molecular formula of $C_{57}H_{98}O_6$. This hypothetical "typical" molecule consists of 77.9 weight % carbon, 11.2 weight % hydrogen, and 10.9 weight % oxygen, which compares quite closely to the actual elemental analysis of the EM-510-F soybean oil.

The base fuel and the three blends were roughly 10% higher in carbon content and almost that much lower in oxygen content than the soybean oil, as expected with materials more like pure hydrocarbons. The three blends had somewhat more oxygen than the base fuel, with the SRC-II blend being highest in oxygen. This result for SRC-II was as expected, given its 3.9% oxygen content in neat form. Sulfur was almost constant among the base fuel and blends, but below detectable limits for the soybean oil. Nitrogen was moderate or low for all the fuels except the SRC-II blend (EM-511-F), which contained 2200 ppm (0.22%), derived almost entirely from the SRC-II material.

Distillation and simulated distillation data showed all the fuels except the soybean oil to have volatility mostly similar to commercial diesel fuels. The lubricating oil in EM-517-F showed up as residue in the D86 test, but as a small concentration in an extremely high-boiling range in the high-temperature D2887 test. As expected, the EM-510-F soybean oil displayed lower volatility than the other fuels. In order to obtain results at all, the soybean oil was diluted 50% with carbon disulfide and run in a shorter-than-normal GC column.

D. Test Procedures

Emissions from the Mack EM6-300 engine were measured during both steady-state and transient engine exercises. Steady-state operation and measurement techniques were based on the 1979 13-mode Federal Test Procedure (FTP).[3] Transient operation and measurement techniques were based on the 1984 FTP and 1986 Proposed FTP, which includes particulate.[1,2]

The 13-mode test procedure is an engine emission test cycle which consists of 13 individual modes of steady-state operation. Starting with a fully warmed engine, the first mode is an idle condition. This idle is then followed by 2, 25, 50, 75 and 100 percent load at intermediate speed followed by another idle mode, then to rated speed - 100, 75, 50, 25, and 2 percent of full load, followed by a final idle mode. Intake air, fuel, and power output are monitored along with other data to be used in calculating modal emission rates. Composite 13-mode emissions are calculated on the basis of modal weighting factors as specified in the Federal Register.[3]

Transient engine operation was performed in accordance with the 1984 Transient FTP for Heavy-Duty Diesel Engines.[1] The procedure specifies a transient engine exercise of variable speed and load, depending on the power output capabilities of the test engine. The cycle requires relatively rapid dynamometer control, capable of loading the engine one moment and motoring it the next. The system used in this program consisted of a GE 200 hp motoring/250 hp absorbing dynamometer coupled to a Midwest 500 hp eddy current (absorbing) dynamometer, with a suitable control system fabricated in-house.

The 1984 Transient cycle is described in the Federal Register by means of percent torque and percent rated speed for each one-second interval, over a test cycle of 1199 seconds duration. The 20-minute transient cycle, developed from heavy-duty truck data, is composed of four five-minute segments. The four segments are described below:

Transeint Cycle

Segment	Time, sec,
New York Non-Freeway (NYNF)	297.
Los Angeles Non-Freeway (LANF)	300.
Los Angeles Freeway (LAF)	305.
New York Non-Freeway (NYNF)	297.

In order to generate the transient cycle for the Mack engine, the engine's full power curve was obtained from 400 rpm to maximum no load engine speed.

Data from this "power curve", or engine map, were used in conjunction with the specified speed and load percentages to form the transient cycle. As an example, a graphic presentation of speed and torque commands which constituted an FTP transient cycle for a 250 hp diesel engine is given in Figure 3. For this example, the resulting cycle work was 11.68 kW-hr (15.66 hp hr) based on a peak torque of 880 N•m (650 ft lbs) and a rated speed of 2200 rpm. The relatively large negative torque commands shown in the figure are to insure that the "throttle," or rack control, goes closed for motoring operation.

The two NYNF segments, which are the initial and final cycle segments of the transient cycle, together contain approximately 23 percent of the total reference work called for by the transient cycle. The LANF segment contains 20 percent and the LAF contains 57 percent of the total transient cycle reference work. This comparison illustrates that most of the work is produced during the LAF cycle segment.

The transient cycle is perceived as a lightly-loaded duty cycle. The average duty cycle over the entire transient cycle is approximately 20 percent of available engine power. The NYNF only calls for an average of 9 percent of the maximum power available from the engine; whereas the LANF calls for approximately 15 percent and the LAF requires about 45 percent. In addition, each NYNF segment contains 165 seconds of idle and 27 seconds of motoring, the LANF segment contains 98 seconds of idle and 79 seconds of motoring, and the LAF segment contains 11 seconds of idle and 45 seconds of motoring.

Of the 1199 seconds of the transient cycle, closed rack commands account for 617 seconds. Therefore, the engine must attempt to produce the reference cycle work within the remaining 582 seconds. These statistics mean that the engine has to produce an equivalent of 40 percent of its maximum power for the remaining "non-idle" time of the cycle (582 seconds). These observations for the transient test stress the relative importance of pollutant emissions during idle, accelerations and medium- to light-load conditions.

A Transient FTP Test consists of a cold-start transient cycle and a hot-start transient cycle. The same engine control or command cycle is used in both cases. For the cold-start, the engine was operated over a "prep" cycle, then allowed to stand overnight in an ambient soak temperature of 20 to 30°C (68 to 86°F). The cold-start transient cycle begins when the engine is cranked for cold start-up. Upon completion of the cold-start transient cycle, the engine is shut down and allowed to stand for 20 minutes. After this hot soak period, the hot-start cycle begins with engine cranking.

All engines react somewhat differently to the transient cycle commands, due to both cycle and engine characteristics. In order to judge how well the engine follows the transient cycle command, engine responses are compared to engine commands using least squares regression techniques, and several statistics are computed. According to the Federal Register, the following regression line tolerances should be met:

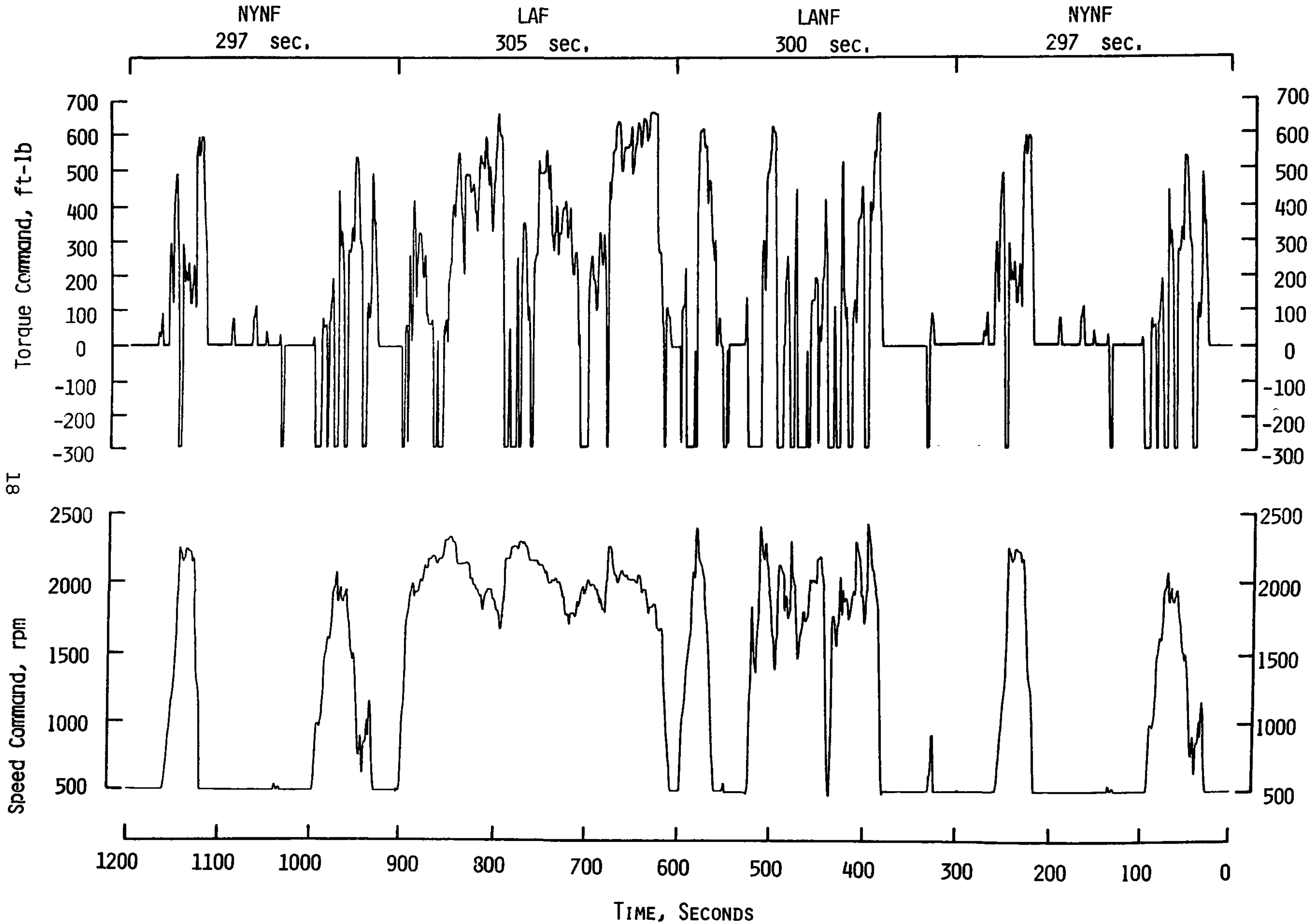

Figure 3. Graphic representation of torque and speed commands for the 1984 Transient FTP cycle for a 186.5 kW at 2200 rpm diesel engine

REGRESSION LINE TOLERANCES

	Speed	Torque	Brake Horsepower
Standard Error of Estimate (SE) of Y on X	100 rpm	13% of Maximum Engine Torque	8% of Maximum Brake Horsepower
Slope of the Regression Line, M	0.970 1.030	0.83-1.03 Hot 0.77-1.03 Cold	0.89-1.02 (Hot) 0.87-1.03 (Cold)
Coefficient of Determination, R^2	0.9700 1/	0.8800 (Hot) 1/ 0.8500 (Cold) 1/	0.9100 1/
Y Intercept of the Regression Line, B	±50 rpm	±15 ft lbs	±5.0 of brake horsepower

1/ Minimum

In addition to these statistical parameters, the actual cycle work produced should not be more than 5 percent above, or 15 percent below, the work requested by the command cycle.

If the statistical criteria are not met, then adjustments to throttle servo linkage, torque span points, speed span points, and gain to and from error feedback circuits can be made in order to modify both the engine output and the dynamometer loading/motoring characteristics. After completion of the cold-start and the hot-start transient cycles, transient composite emissions results are computed by the following:

$$\text{Brake Specific Emissions} = \frac{1/7\ (\text{Mass Emissions, Cold}) + 6/7\ (\text{Mass Emissions, Hot})}{1/7\ (\text{Cycle Work, Cold}) + 6/7\ (\text{Cycle Work, Hot})}$$

The engine was also operated over the 1979 Smoke FTP exercise. It essentially consists of a 5-minute idle followed by full throttle acceleration to rated speed, and finally, a full throttle lug-down from rated speed to intermediate speed. This transient smoke test cycle was run only for the measurement of visible smoke emissions.

E. Analytical Procedures

The analytical systems used for each category of emission measurements are described in this section. The section is divided into two parts, the first dealing with gaseous emissions characterization and the second with total particulate emissions and the constituents of the total particulate. Gaseous emissions included HC, CO, CO_2, NO_x, and some unregulated pollutants. Unregulated gaseous emissions included individual hydrocarbons, aldehydes, phenols, and odor. Particulate emissions included determination of the total particulate mass, and its content of metals, carbon and hydrogen. The size distribution of the particles was determined, as well as the fraction soluble in methylene chloride. This soluble fraction was characterized for BaP content, bioactivity by the Ames test, boiling point distribution, fractionation (by relative molecular polarity), and for carbon and hydrogen content.

During steady-state or modal engine exercises, regulated and some unregulated gaseous emissions can be sampled from the raw exhaust stream since a representative and proportional sample can be obtained. Obtaining proportional samples during transient engine operation required the use of a constant volume sampler (CVS).[1,2] All transient cycle test work run for regulated emissions of HC, CO, NO_x as well as particulate was conducted with a main tunnel flow of 2000 SCFM, which provided approximately a 4:1 cycle dilution ratio of the total exhaust introduced. Unregulated gaseous emissions of aldehydes, individual hydrocarbons, phenols, and odor were sampled from the primary tunnel during the transient testing. During these runs for regulated emissions, particulate mass emissions were determined by use of a small secondary dilution tunnel. This small secondary tunnel, shown in Figure 4, is attached to the primary tunnel and dilutes the primary dilute exhaust further to an overall ratio of about 12:1. The small secondary dilution tunnel was operated at approximately 4 SCFM total flow in order to collect particulate on two 90 mm T60A20 Pallflex filters, in series. Weight gains from these two filters were used to determine the total particulate mass emission from the engine.

In order to obtain large particulate samples and for particle sizing during transient operation, the primary tunnel was operated as a single-dilution CVS. To obtain approximately a 12:1 dilution ratio, the CVS flow was increased to about 5000 SCFM during the transient cycle which permitted collection of large quantities of particulate on 20x20 inch filters.

Large filter holders and the associated tunnel are shown in Figure 5. This same CVS system was used to collect particulate samples from steady-state operation of the engine, by altering the secondary dilution tunnel flow to accommodate the total exhaust from the engine without exceeding 52°C (125°F) at the particulate filter face.

1. Gaseous Emissions

Regulated gaseous emissions of HC, CO, and NO_x were measured according to the 1979 13-mode FTP and the 1984 transient FTP. The regulated emissions along with CO_2 were determined from raw exhaust samples taken during the 13-mode steady-state procedure. These same four constituents were determined in dilute exhaust samples taken during the transient procedure. The transient procedure required that HC be determined from integration of continuous concentration monitoring of the CVS dilute exhaust. The procedure provides the option of determining CO, CO_2 and NO_x from either dilute sample bags or from integration of continuous concentration monitoring.

Hydrocarbons were measured over both test procedures using the specified heated sample train (190°C). During steady-state operation, raw exhaust sample was transferred to a hydrocarbon instrument containing a Beckman 402

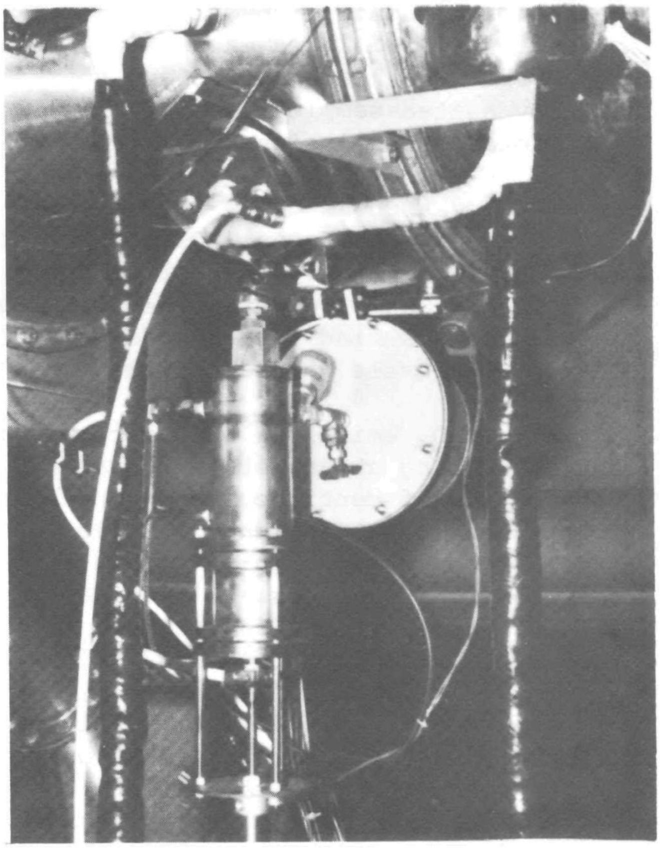

Figure 4. Secondary dilution tunnel for particulate mass rate by 90 mm filters

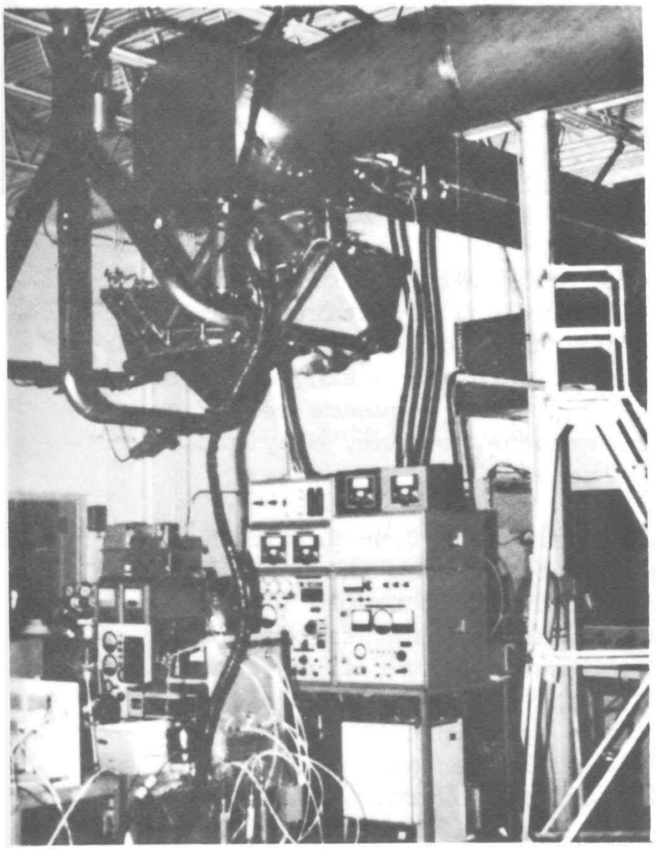

Figure 5. Filter holders for large particulate sample acquisition

heated flame ionization detector (HFID) by heated sample line. During transient operation, CVS-diluted exhaust was taken from the main dilution tunnel using the prescribed heated probe and heated filter, and was transferred to the 402 HFID by heated sample line.[2] The intent of both procedures is to determine the "total" HC emissions from the engine under test.

Carbon monoxide was measured during both engine test procedures using non-dispersive infrared (NDIR) instruments. Emissions of CO_2 were also determined by NDIR for use in fuel consumption calculations by carbon balance. Both CO and CO_2 were determined from raw exhaust samples transferred by heated sample lines during the 13-mode procedure. During transient test procedures, CO and CO_2 levels were determined from proportional dilute exhaust bag samples.

NO_x emissions were determined by chemiluminescence (CL) from raw exhaust during steady-state operation, and from both dilute sample bags and integration of continuous NO_x concentration monitoring during transient operation. The transient NO_x level determined from the bag sample has generally been lower (5-15 percent) than that indicated by continuous NO_x measurement techniques.[23] No NO_x correction factor for intake humidity was applied for transient testing because the engine intake humidity and temperature were controlled to 60-90 grains/lb of dry air and 68-86°F.

Some selected individual hydrocarbons (IHC) were determined from dilute exhaust bag samples taken over the cold-start and hot-start transient cycles using the CVS. A portion of the exhaust sample collected in the Tedlar bag was injected into a four-column gas chromatograph using a single flame ionization detector and dual sampling valves. The timed sequence selection valves allowed the baseline separation of air, methane, ethane, ethylene, acetylene, propane, propylene, benzene, and toluene.[24]

Aldehydes and ketones were determined using the 2,4-dinitrophenylhydrazine (DNPH) method.[24] Dilute samples were taken from the main CVS dilution tunnel during transient testing. A heated Teflon sample line and filter were maintained at 190°C (375°F). The procedure consists of bubbling filtered exhaust gases, dilute or raw, through glass impinger traps containing a solution of DNPH and hydrochloric acid (HCl) kept near 0°C. The aldehydes form their respective phenylhydrazone derivatives (precipitates). These derivatives are removed by filtration and followed by pentane extractions and evaporation in a vacuum oven. The remaining dried extract, which contains the phenylhydrazone derivatives, is dissolved in a specific volume of methanol. A portion of this dissolved extract is injected into a high performance liquid chromatograph and analyzed using a UV spectrophotometer as a detector, to separate formaldehyde, acetaldehyde, acrolein, propionaldehyde, acetone, crotonaldehyde, isobutyraldehyde, methylethylketone, hexanaldehyde, and benzaldehyde.

Phenols, which are hydroxyl derivatives of aromatic hydrocarbons, were measured using an ether extraction procedure detailed in Reference 24. Dilute samples were taken from the main CVS dilution tunnel during transient operation only. Dilute exhaust samples were filtered and collected in impingers containing aqueous potassium hydroxide. The contents of the impingers were acidified with sulfuric acid, then extracted with ethyl ether. This extract was injected into a gas chromatograph equipped with an FID in order to separate 11 different phenols ranging in molecular weight from 94.11 to 150.22.

Total intensity of aroma (TIA) was quantified by using the Coordinating Research Council Diesel Odor Analytical System (DOAS). CVS-diluted exhaust was drawn off through a heated sample train and into a trap containing Chromosorb 102. The trap was later eluted and injected by syringe into the DOAS instrument, which is a liquid chromatograph that separates an oxygenate fraction (liquid column oxygenates, LCO) and an aromatic fraction (liquid column aromatics LCA). The TIA values are defined as:

$$TIA = 1 + \log_{10} (LCO, \mu g/\ell)$$

or

$$TIA = 0.4 + 0.7 \log_{10} (LCA, \mu g/\ell) \quad \text{(TIA by LCO preferred)}$$

A.D. Little, the developer of the DOAS instrument, has related this fraction to TIA sensory measurement by the A.D. Little odor panel.[25] The system was intended for raw exhaust samples from steady-state operating conditions, but for this program, dilute samples of exhaust were taken in order to determine a TIA value for transient operation. Where dilute samples were taken, the resulting values were increased in proportion to the dilution ratio.

2. Particulate Emissions

Particulate emissions were determined from dilute exhaust samples utilizing various collection media and apparatus, depending on the analysis to be performed. Particulate has been defined as any material collected on a fluorcarbon-coated glass fiber filter at or below a temperature of 51.7°C (125°F), excluding condensed water.[2] The 125°F temperature limit and the absence of condensed water dictates that the raw exhaust be diluted, irrespective of engine operating mode. The temperature limit generally required dilution ratios of approximately 12:1 (total mixture:raw exhaust).

Total particulate samples were collected on 90 mm Pallflex T60A20 fluorocarbon-coated glass fiber filter media by means of a double-dilution technique for both transient and steady-state engine operation. Gravimetric weight gain, representing collected particulate, was determined to the nearest microgram after the filter temperature and humidity were stabilized. This weight gain, along with CVS flow parameters and engine data, were used to calculate the total particulate mass emission of the engine under test.

Smoke and total particulate are related in that the relative level of smoke opacity indicates the relative level of particulate. The absence of smoke, however, does not indicate the absence of particulate. Smoke was determined by the end-of-stack EPA-PHS smokemeter, which monitored the opacity of the raw exhaust plume as it issued from the 4 inch diameter exhaust pipe. Smoke opacity was determined for 13-mode operation, power curve operation, and for the smoke FTP.[3]

Since total particulate, by definition, includes anything collected on fluorocarbon-coated glass fiber filter media, there has always been a interest in finding out what constitutes the "total particulate." The following paragraphs describe the methods and analysis used to determine some of the properties of the total particulate.

A particulate size distribution of particulate generated over the transient cycle was determined using a Sierra Series 220 cascade inertial impactor. Dilute exhaust particles having a variety of shapes and densities were fractionated and collected according to their aerodynamic characteristics. The aerodynamic size gives information relating to the physical size, shape, and density of the particulate, indicating how the particles may behave in the environment. Pre-weighed fluorocarbon-coated glass fiber filters were used as back-up filters to collect all particulate aerodynamically smaller than the lowest stage cut-off size (0.10 microns Effective Cut-Off Diameter, or ECD). Impactor flow rate was selected to provide individual stage separation from 7.0 to 0.10 microns ECD.

Sulfate, originating from the combustion of sulfur-containing fuel, was collected as part of the particulate matter in the form of sulfate salts or sulfuric acid aerosols. A 47 mm Fluoropore (Millipore Corp.) fluorocarbon membrane filter with 0.5 micron pore size was used to collect the sample. This total particulate sample is ammoniated to "fix" the sulfate portion of the particulate. Using the barium chloranilate (BCA) analytical method, the sulfates are leached from the filter with an isopropyl alcohol-water solution (60% IPA). This extract is injected into a high pressure liquid chromatograph (HPLC) and pumped through a column to scrub out the cations and convert the sulfate to sulfuric acid. Passage through a reactor column of barium chloranilate crystals precipitates out barium sulfate and releases the highly UV-absorbing chloranilate ions. The amount of chloranilate ion released is determined by a sensitive liquid chromatograph UV detector at 310-313 nanometers. "Sulfate" should be understood to mean $SO_4^=$ as measured by the BCA method.[24]

Carbon, hdyrogen, metals, and other elements that make up the total particulate are also of interest. A sample of "total particulate" was collected on 47 mm Type A (Gelman) glass fiber filter media for the purpose of determining the carbon and hydrogen weight percentages. This analysis was performed by Galbraith Laboratories using a Perkin-Elmer Model 240B automated thermal conductivity CNH analyzer. A sample of total particulate matter was also collected on a 47 mm Fluoropore filter for the determination of trace elements such as calcium, aluminum, phosphorus, and sulfur by x-ray fluorescence. This analysis was conducted at the EPA, ORD laboratories in Research Triangle Park, North Carolina using a Siemens NRS-3 X-ray fluoresence spectrometer.

Diesel particulate generally contains significant quantities of condensed fuel-like or oil-like hydrocarbon aerosols generated during incomplete combustion. In order to determine to what extent total particulate contains these various hydrocarbons, large particulate-laden filters (20x20 inch) were washed with an organic solvent, methylene chloride, using 500 mℓ soxhlet extraction apparatus. The dissolved portion of the "total particulate" carried off with the methylene chloride solvent has been referred to as the "soluble organic fraction " (SOF). All filter handling, extraction processes, and handling of concentrated SOF were carried out according to EPA recommended protocol.[26] The SOF may be composed of anything carried over by the extraction process, so its composition is also of interest. Generally the SOF contains numerous organic compounds, many of which are difficult to isolate and quantify. Most diesel SOF has been shown to be mutagenic using the Ames test.

BaP is considered to be an elementary indicator of the relative PNA content of the SOF. The analytical method used for the determination of BaP is described in Reference 27. The procedure is based on high-performance liquid chromatography to separate BaP from other organic solubles in particulate matter, and it incorporates fluorescence detection to measure BaP. The instrument used was a Perkin Elmer 3B liquid chormatograph equipped with a MPF-44 fluorescence spectrophotometer. Excitation was at a wavelength of 383 nm, and emission was read at 430 nm.

Samples of SOF were submitted for Ames testing. The Ames test, as employed in this program, refers to a bacterial mutagenesis plate assay with Salmonella typhimurium according to the method of Ames.[28] This bioassay determined the ability of chemical compounds or mixtures to cause mutation of DNA in the bacteria, positive results occurring when histidine-dependent strains of bacteria revert (or are mutated) genetically to forms which can synthesize histidine on their own. Samples of SOF were shipped under dry ice or EG&G* for Ames test response.

The boiling range of the SOF was determined by SwRI's Mobile Energy Research Division using a high-temperature variation of ASTM-D2887-73. Approximately 50 mg of the SOF was dissolved in solvent and an internal standard (C_9 to C_{11} compounds) was added. This sample was then submitted for instrumental analysis of boiling point distribution. In some cases, insufficient sample was available to use internal standards.

Another portion of the SOF sample was submitted for fractional separation. The method involves separation of the extractables into a series of fractions of increasing polarity. A high performance liquid chromatographic

*EG&G Mason Research, Inc. is now Microbiological Associates, Inc, 5221 River Road, Bethesda, Maryland 20816. These analyses were done under a separate EPA Contract (68-03-2923) procedure which utilized a variable solvent program was used to elute increasingly polar compounds. BaP, 9-fluorenone and acridine standards are injected to indicate the types of compounds eluted in each region of the chromatogram.[29]

IV. RESULTS

This section describes the results obtained from numerous emission measurements and sample analyses conducted on the Mack EM6-300 Heavy-Duty Diesel Engine. It is divided into three parts. The first part describes some of the pertinent details and the chronology of the accumulated test results. The next two parts detail the accumulated gaseous and particulate data, respectively. Overall emission trends and general remarks are given along with the results.

A. General Test Notes

The Mack EM6-300 engine, S/N 4779, arrived in good condition on November 16, 1981. This engine had been tested by Mack prior to shipment in order to obtain 13-mode and transient gaseous emissions as well as Federal smoke emissions. Actual start-up of the test program was delayed due to difficulties associated with obtaining the test fuels and ongoing test work on the M.A.N. methanol engine, another Task under this EPA Contract. The test engine was installed in the transient-capable test facility, cell 4, and engine operation on the baseline fuel (Phillips D-2, SwRI Code EM-509-F) was begun May 6, 1982. A 4-inch diameter intake system and a 5-inch diameter exhaust system was used. Static pressure measuring sections for these intake and exhaust systems were fabricated according to Mack "specification of procedure 312 GS 148." The engine was operated over transient and steady-state conditions using the intake restriction and exhaust backpressure schedule given in Table 6. In addition, the set points for the temperature control "test cell" intercooler are given in Table 6.

TABLE 6. INTAKE AND EXHAUST PRESSURE PARAMETERS FOR TESTING THE MACK EM6-300[a]

	Intake Restriction		Exhaust Backpressure		
	Theoretical mm H_2O (in. H_2O)	Indicated mm H_2O (in. H_2O)	Theoretical mm Hg (in. Hg)	Indicated mm Hg (in. Hg)	Intercooler Temperature °C (°F)
Transient	510 (20.0)	770 (30.3)	38 (1.5)	28 (1.1)	43 (110)
Steady-State	640 (25.0)	900 (35.3)	76 (3.0)	66 (2.6)	49 (120)

[a]These conditions were set during full rack and rated speed condition

Under initial steady-state operation the engine developed about 3 percent higher power than obtained by Mack. This was associated with a slightly higher measured fuel consumption (1.2 percent). Following preliminary engine operation checkouts, the engine was mapped according to the transient test procedures and preliminary transient tests were conducted to make dynamometer adjustments necessary to meet the statistical requirements. Two cold- and hot-start transient tests for gaseous regulated and unregulated emissions were completed prior to running the Federal smoke test.

Results from the Federal smoke test indicated higher "a" (acceleration) factor smoke numbers (>20 percent opacity) than obtained by Mack. Aneriod supply pressure was found to be around 80 psi instead of the desired level of 90 psi. A suitable regulated air supply was obtained and the smoke procedure was repeated. The "a' factor smoke opacity over the Federal smoke cycle repeated, and was still over 20 percent opacity. No definite problem was found. Adjustment to the aneroid mechanism could have been made, but it was recommended by Mack that no adjustment to the fuel injection pump or aneroid be made due to the possibility of creating more problems while trying to make the adjustments for slightly lower acceleration smoke. An additional cold- and hot-start transient test was conducted, indicating that the increase of aneriod supply pressure had no detectable effect on either gaseous or particulate emissions.

The CVS flow was increased from 2000 cfm to 5000 cfm, and 11 modes of particulate were taken via the 90 mm double dilution system. Replicate steady-state runs for particulate were made, one for 5 minutes duration and another for 15 minutes duration. One cold-start and two hot-start transient tests were conducted to obtain large particulate samples needed for the characterization of the soluble organic fraction. In addition, two 13-mode test sequences for regulated gaseous emission were completed on the baseline fuel.

The fuel supply system, which included a fuel drum, Flo-tron, return tank, and engine fuel filter, were changed over to the next test fuel, EM-515-F, a blend of 25 percent Exxon Donor Solvent (EDS) middle distillate with the baseline fuel. Following a flush sequence which included 15 minutes of rated power operation, preparations were made to begin the testing outlined in the test plan for this fuel (see page 8 of this report). The rated power and maximum torque over the 13-mode test were 2.4 percent and 2.3 percent higher with the EDS blend. For comparison purposes, it was decided that the 13-mode test would be run at the same load conditions at the various modes as obtained for the baseline fuel, with the exception of full rack conditions of 2100 rpm/100 percent load and 1260 rpm/100 percent load. Similarly, it was decided that comparison of fuel effects over the transient cycle could be best served by operating the engine with the same transient command cycle as established for the baseline fuel. In this way, it was rationalized that the engine would be requested to perform as though on baseline fuel; and thus emissions would reflect only the effect of the alternate fuel used on the unmodified engine. The engine performed well on the EDS blend and no problems were encountered.

After completing emissions testing on this fuel, the fuel system was changed over to EM-511-F, a blend of 25 percent Solvent Refined Coal (SRC-II) middle distillate, with baseline fuel. This fuel blend was very dark in color, and had a very strong odor. Precautions were taken to reduce personnel exposure by direct contact and inhalation. The fuel had an odor which resembled that of a concentrated engine degreasing compound marketed under the name of "Gunk." The rated power on this fuel blend was 0.7 percent higher and the maximum torque over the 13-mode test was 0.3 percent higher than with the baseline fuel. The engine performed well on the SRC-II blend, and no problems were encountered.

Upon completion of emissions testing and sample acquisition, the fuel system was changed over to EM-517-F, a blend of 5 percent used (filtered) diesel crankcase oil and baseline fuel. This prepared fuel blend was opaque due to suspended carbon black from the used lube oil. The rated power and the maximum torque over the 13-mode test with the lube oil blend were 0.4 and 1.0 percent higher than obtained with the baseline fuel. No problems were encountered, and the emissions testing and sample acquisition were completed June 5, 1982.

Preparations for operating the engine on "once refined" neat soybean oil, fuel code EM-510-F, included the insulation and heating of the fuel system starting with the bulk drum (55 gallon drum), and going all the way to the gallery of the fuel injection pump. A total of approximately 5 kW were available for heating the fuel (rated power fuel rate of 54 kg soybean oil/hr) to the desired 145±6°C (290°F±10°F) at the inlet to the fuel injection pump. The final stage of heating took place at the fuel filter, which was wrapped with a 500 watt heater and well insulated. As the soybean oil heating system evolved, the engine transfer pump failed due to melting of the plastic check valves within the pump. A gear-type transfer pump was installed in the system, external to the engine. The injector lines from the fuel injection pump to the individual injectors were also wrapped with insulation. All emissions testing was conducted with the soybean oil at 145±6°C. The rated power dropped 19.7 percent and the maximum torque fell off 13.7 percent over the 13-mode test from baseline fuel levels. Aside from the noticeable drop in power at the full rack condition, no engine operational problems were encountered, and the operators noted that the engine seemed to run more quietly. No "cold-start" problems were noted, although the soybean oil was brought to 145°C before engine cranking was begun. Even though the rated power and maximum torque were lower, the transient test statistical criteria were still met, primarily due to the elimination of test points where the engine could not reach the command torque with full rack. Once emissions testing was completed, the fuel system was converted to baseline fuel configuration.

Prior to operating the engine on the baseline fuel again, the injectors were pulled and inspected. Figure 6 illustrates the deposits noted on all six of the injectors. As expected, the deposits were fairly heavy. Each nozzle spray hole was surrounded by a small cup-shaped deposit about 1 mm deep. This formation was soft on the surface with harder deposits closer to the metal nozzle tip. The deposits were removed and the injectors were installed. The damaged (melted check valves) transfer pump was replaced and the fuel system purged. The engine was operated for approximately 2 hours on the baseline fuel in an attempt to flush whatever deposits may have been left by the soybean oil. The engine produced rated power and maximum torque equivalent to the levels observed during initial testing on the baseline fuel. The engine was removed from the test facility June 22, 1982. Approximately 280 gallons of baseline fuel, and about 130 gallons of each of the alternate fuels or fuel blends were consumed during this test program.

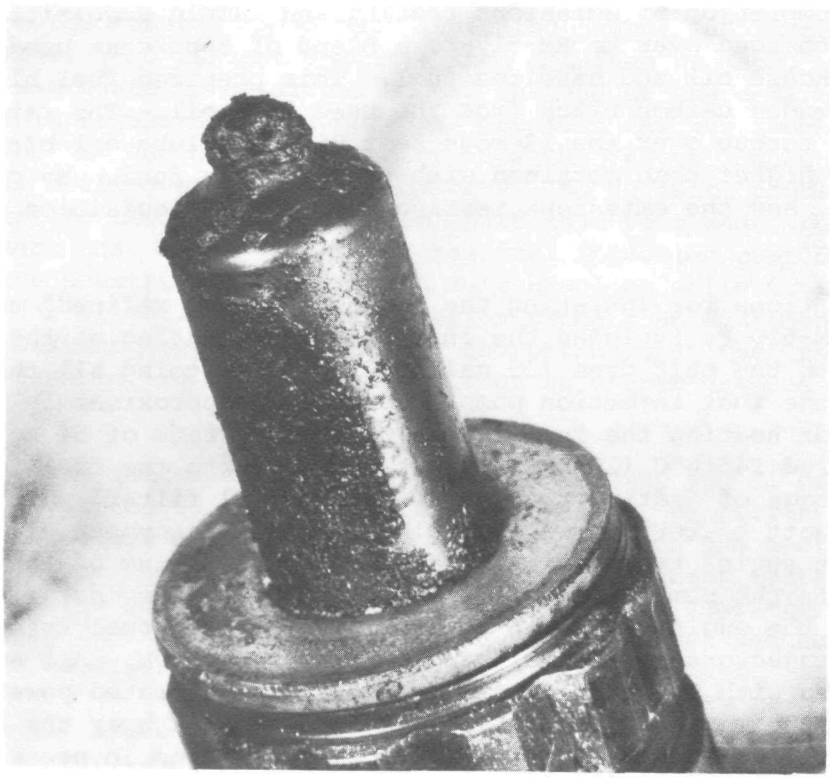

Figure 6. Nozzle tip from Mack EM6-300 after completion of testing with neat soybean oil heated to 145±6°C

B. Gaseous Emissions

The term "gaseous emissions" usually refers to HC, CO, and NO_x, which are emissions regulated by EPA. This section presents the results of emission measurements which include not only these regulated gaseous emissions, but also selected individual hydrocarbons, aldehydes, and phenols. Odor intensity, which has been shown to correlate with the presence of these and other gas phase emissions, is also presented.

1. HC, CO, and NO_x

These regulated pollutants were measured over the 1979 FTP as well as the 1984 Transient FTP. In 1984, the transient test procedure will be optional in lieu of the 13-mode test procedure. In 1985, the transient test procedure will become mandatory, and in 1986 the transient test procedure will include particulate measurement and regulation. For perspective, some of the proposed standards, beyond 1979, are listed below:

Model Year	FTP	Regulated Emissions, (g/hp-hr) HC	CO	NO_x	Particulate
1979	13-mode	1.5	25.	10.0	None
	13-mode (opt.)	--	25.	5.0	None
1984	13-mode[b]	0.5[c]	15.5[d]	9.0	None
	Transient[b]	1.3	15.5[d]	10.7	None
1985	Transient	1.3	15.5[d]	10.7	None
1986	Transient	1.3	15.5[d]	4.0[e]	0.25[e]

[a]Federal Smoke Regulations apply
[b]Manufacturer may certify by either procedure
[c]Subject to revision to 1.0 g/hp-hr
[d]CO measurement requirements for Heavy-Duty Diesels may be waived after 1983
[e]Proposed (not finalized)

a. 13-Mode FTP

Two 13-mode Federal Test Procedures for gaseous emissions were conducted on the Mack EM6-300 for each of the five test fuels. The results from these individual tests are given in Table 7 along with average values for comparison purposes. Emission results from 13-mode testing with the baseline fuel compared reasonably well with manufacturer's data, and indicated that the engine was operating properly. In addition to normal operational checkout, full load performance parameters were recorded during acquisition of full power curve smoke data, and these data are given in Appendix A, Table A-1. This particular engine is marketed as a fuel-efficient engine, and BSFC over the 13-mode test was relatively low especially compared to similar-size engines run under the EPA Baseline project.(23) Detailed results from these two 13-mode tests run on baseline fuel are given in Appendix Tables A-2 and A-3, and give emissions information on a modal basis.

Full power curve data obtained with the 25 percent EDS blend are given in Appendix B, Table B-1, and indicate slightly higher power output along with higher fuel rates. Average results from the 13-mode tests, given in Table 7, indicate essentially the same level of 13-mode composite HC, while CO emissions decreased 9.7 percent, and NO_x emissions increased 12 percent over levels obtained with the baseline fuel. From the individual 13-mode printouts given in Appendix B, Tables B-2 and B-3, these changes in 13-mode composite emissions were well distributed over all the modes of steady-state operation. No change in BSFC was noted.

TABLE 7. GASEOUS EMISSION SUMMARY FROM 13-MODE OPERATION OF MACK EM6-300 ENGINE

Test Fuel	Run No.	13-Mode Emissions, g/kW-hr, (g/hp-hr) HC	CO	NO_x	BSFC kg/kW-hr (lb/hp-hr)
Baseline EM-509-F	01-01	0.854 (0.637)	3.266 (2.436)	9.933 (7.410)	0.234 (0.384)
	01-02	0.839 (0.626)	3.224 (2.405)	10.174 (7.590)	0.232 (0.382)
	Avg.	0.847 (0.632)	3.246 (2.421)	10.054 (7.500)	0.233 (0.383)
25% EDS EM-515-F	02-01	0.838 (0.625)	2.891 (2.157)	11.168 (8.331)	0.236 (0.387)
	02-02	0.843 (0.629)	2.968 (2.214)	11.363 (8.477)	0.233 (0.383)
	Avg.	0.840 (0.627)	2.930 (2.186)	11.265 (8.404)	0.234 (0.385)
25% SRC-II EM-511-F	03-01	0.932 (0.695)	3.466 (2.586)	11.334 (8.455)	0.234 (0.385)
	03-02	0.883 (0.636)	3.404 (2.540)	11.320 (8.445)	0.235 (0.387)
	Avg.	0.908 (0.677)	3.435 (2.563)	11.327 (8.450)	0.235 (0.386)
5% Lube Oil EM-517-F	04-01	1.016 (0.758)	2.730 (2.037)	10.204 (7.612)	0.233 (0.384)
	04-02	1.064 (0.794)	2.638 (1.968)	10.456 (7.800)	0.230 (0.378)
	Avg.	1.040 (0.776)	2.684 (2.002)	10.330 (7.706)	0.232 (0.381)
Soybean Oil EM-510-F	05-01	0.471 (0.352)	2.605 (1.943)	9.127 (6.809)	0.276 (0.454)
	05-02	0.394 (0.294)	2.674 (1.995)	9.300 (6.938)	0.274 (0.451)
	Avg.	0.433 (0.323)	2.640 (1.969)	9.214 (6.873)	0.275 (0.452)

The third test fuel run was a blend of 25 percent Solvent Refined Coal (SRC-II) middle distillate and baseline fuel. Full load performance, given in Appendix C, Table C-1, was very similar to that obtained with baseline fuel. Over the 13-mode test, the composite HC and CO emissions increased 7 and 6 percent over baseline levels, respectively. The 13-mode composite NO_x emissions were similar to those obtained for the EDS blend, and were 13 percent above the baseline fuel's NO_x level. From the individual modal information given in Appendix C, Tables C-2 and C-3, the increase in CO was primarily due to significant increases during 2 percent load conditions. Similar to the EDS blend, no change in BSFC was noted with the SRC-II blend.

No significant change in full load performance was noted with a blend of 5 percent (used, filtered) crankcase oil and baseline fuel. Relative to composite emission levels over the 13-mode test on the baseline fuel, the 5 percent lube oil caused the HC level to increase by 23 percent, the CO level to decrease by 17 percent, and the NO_x level to increase by nearly 3 percent. Detailed 13-mode computer printouts, Tables D-2 and D-3 of Appendix D, indicate that the changes noted were distributed over most of the modes of steady-state operation. No change in BSFC was noted over the 13-mode test.

The fifth test fuel was neat soybean oil, heated to approximately 145°C in order to provide a viscosity which resembled that of diesel fuel. Although the heating value of this soybean oil was 10.5 percent below the baseline diesel fuel, the rated power dropped by about 20 percent. Similar reductions in power were noted over the entire power curve speed range, given in Table E-1 of Appendix E. Since the soybean oil contained 9.9 percent oxygen, 13-mode emission computations were modified slightly. A hydrogen-to-carbon ratio of 1.77 and an oxygen-to-carbon ratio of 0.096 were used to process the 13-mode emissions. These two ratios were used in computing stoichiometric and actual f/a ratios, HC wet-to-dry correction and NO_x correction factors. Even though the validity of the NO_x correction factor for intake humidity is uncertain for this fuel, it was applied to the results for comparison purposes. Hydrocarbon emission data from this fuel were computed using a molecular weight of 15.43 per carbon atom. No correction for possible variations in FID response to unburned soybean oil exhaust constituents was used. Computer printouts from the two 13-mode tests are given in Tables E-2 and E-3 of Appendix E, and indicate additional computed f/a ratios on a modal basis. To facilitate comparison of fuel effects, no adjustments to 13-mode load settings were undertaken; for example, the 50 percent load condition was run at the load setting obtained with baseline fuel, and not based on that computed from full load obtained with the neat soybean oil. Therefore, the 13-mode composite results are somewhat distorted, since maximum full loads at rated and intermediate speeds were significantly less than with the baseline fuel, but the part load conditions (75 through 2 percent) were run at the same loads as obtained with the baseline fuel. This method of operation still indicates emissions levels during full load conditions as achieved, but are not as comparable as if the maximum fuel rate had been increased to obtain the baseline power.

Results from the 13-mode composite run with soybean oil indicate about 49 percent lower HC, 19 percent lower CO and 8.5 percent lower NO_x than obtained with the baseline fuel. Comparisons of modal conditions, other than at full rack, showed lower brake specific HC's over all modes. Similarly, brake specific CO was lower for the 50 and 75 percent load conditions, but higher for the 2 and 25 percent conditions as well as during idle (g/hr). Lower NO_x emissions were noted during the lightly loaded modes, and especially idle. The 13-mode composite BSFC increased 18 percent over that obtained with baseline fuel.

These emission trends noted for fueling with neat soybean oil are similar to those generally noted for a retardation of timing. It is possible that even though the injection timing was not changed mechanically, the combustion of soybean oil may be such that a longer ignition delay occurred, resulting in retarded timing.

b. Transient FTP

Transient emissions were measured and calculated in accordance with the 1984 Transient Federal Test Procedure and the 1986 Proposed Transient Federal Test Procedure (which includes particulate). A transient power map of the engine was conducted using the transient restrictions and slave intercooler setpoints discussed earlier (Table 6). The resulting rpm and torque data used to generate the transient command cycle control program are listed in Table A-4 of Appendix A. In addition, the work called for by the command cycle has been listed for each cycle segment along with the total of all four segments. Preliminary transient cycles were conducted and the dynamometer/engine controls were adjusted to improve the statistical results. To facilitate alternate fuel comparisons to the baseline fuel, the same command cycle established with the baseline fuel was used in testing the alternate fuels. This was to simulate an operator switching to an alternate fuel and demanding the same performance from the engine as obtained with the baseline fuel.

The average results from individual transient tests for the five fuels are given in Table 8, and include the average transient composite emission levels of HC, CO, NO_x and particulate. Summary tables of the individual tests and computer printouts corresponding to each cold- and hot-start processed with continuous and bag NO_x are given in each of the Appendices corresponding to each of the five fuels. The computer printouts present the data on a test segment basis, which indicates the relative contribution from various test segments. Statistical results from the individual tests are given in the corresponding Appendix for each fuel. Although particulate data are presented in Table 8, discussion of these transient particulate levels will be reserved for later.

Three cold- and hot-start transient sequences were conducted on the baseline fuel to establish the average transient cycle composites given in Table 8. These results compared fairly well to those obtained by Mack prior to engine shipment. The resultant HC was 20 percent lower, CO was 11 percent higher, bag NO_x was 2 percent lower, and particulate was 18

TABLE 8. REGULATED EMISSIONS SUMMARY FROM TRANSIENT FTP OPERATION OF THE MACK EM6-300 ENGINE

Test Fuel	Cycle Type	Regulated Emissions, g/kW-hr (g/hp-hr) HC	CO	NO_x Cont.	NO_x Bag	Part.	Cycle BSFC kg/kW-hr (lb/hp-hr)	Cycle Work kW-hr (hp-hr)
Baseline EM-509-F	Avg. Cold Start	0.87 (0.65)	4.95 (3.70)	10.32 (7.70)	8.59[a] (6.41)	0.85 (0.63)	0.268 (0.441)	16.33 (21.89)
	Avg. Hot Start	0.90 (0.67)	4.36 (3.25)	10.15 (7.57)	8.68[a] (6.47)	0.78 (0.58)	0.263 (0.432)	16.15 (21.65)
	Avg. Transient Composite	0.90 (0.67)	4.45 (3.32)	10.18 (7.59)	8.65[a] (6.46)	0.79 (0.59)	0.263 (0.432)	16.18 (21.68)
25% EDS EM-515-F	Avg. Cold Start	0.99 (0.74)	5.15 (3.84)	11.32 (8.44)	9.85 (7.34)	0.75 (0.56)	0.270 (0.444)	15.98 (21.43)
	Avg. Hot Start	0.87 (0.65)	4.22 (3.14)	11.10 (8.28)	9.75 (7.27)	0.70 (0.52)	0.260 (0.429)	16.02 (21.47)
	Avg. Transient Composite	0.88 (0.66)	4.35 (3.24)	11.14 (8.31)	9.76 (7.28)	0.70 (0.53)	0.262 (0.431)	16.01 (21.46)
25% SRC-II EM-511-F	Avg. Cold Start	0.99 (0.74)	5.91 (4.41)	12.16 (9.07)	10.00 (7.46)	0.76 (0.56)	0.278 (0.457)	16.04 (21.50)
	Avg. Hot Start	0.81 (0.60)	4.74 (3.53)	12.33 (9.20)	9.53 (7.11)	0.66 (0.49)	0.264 (0.433)	16.18 (21.70)
	Avg. Transient Composite	0.84 (0.62)	4.91 (3.66)	12.31 (9.18)	9.60 (7.16)	0.67 (0.50)	0.266 (0.438)	16.16 (21.66)

[a]Average of 2

TABLE 8 (Cont'd). REGULATED EMISSIONS SUMMARY FROM TRANSIENT FTP OPERATION OF THE MACK EM6-300 ENGINE

Test Fuel	Cycle Type	Regulated Emissions, g/kW-hr (g/hp-hr) HC	CO	NO_x Cont.	NO_x Bag	Part.	Cycle BSFC kg/kW-hr (lb-hp-hr)	Cycle Work kW-hr (hp-hr)
5% Lube Oil EM-517-F	Avg. Cold Start	0.99 (0.74)	4.78 (3.56)	10.87 (8.11)	9.06 (6.76)	0.90 (0.67)	0.274 (0.450)	15.94 (21.36)
	Avg. Hot Start	0.98 (0.73)	4.21 (3.14)	10.72 (7.99)	9.10 (6.79)	0.82 (0.61)	0.262 (0.430)	16.02 (21.48)
	Avg. Transient Composite	0.98 (0.73)	4.29 (3.20)	10.74 (8.01)	9.09 (6.78)	0.83 (0.62)	0.264 (0.434)	16.01 (21.46)
Soybean Oil EM-510-F	Avg. Cold Start	0.70 (0.52)	5.59 (4.17)	7.72 (5.76)	6.58 (4.91)	1.49 (1.11)	0.317 (0.522)	15.26 (20.47)
	Avg. Hot Start	0.46 (0.35)	3.78 (2.82)	7.84 (5.85)	6.70 (4.99)	0.89 (0.67)	0.298 (0.490)	15.57 (20.88)
	Avg. Transient Composite	0.49 (0.37)	4.04 (3.01)	7.82 (5.84)	6.68 (4.98)	0.98 (0.73)	0.301 (0.494)	15.53 (20.82)

percent higher than the transient composite levels reported by Mack. No comparative figures were supplied by Mack for BSFC or cycle power obtained over the transient test. All transient brake specific emission rates (excluding continuous NO_x) were slightly higher and transient BSFC was almost 13 percent higher than obtained over the 13-mode test on the baseline fuel. On the baseline fuel, all emissions and BSFC were slightly higher over the cold-start transient than over the hot-start, but the differences were relatively small.

The average results from two transient sequences run with the EDS blend are given in Table 8. Gaseous emission results from both tests showed good repeatability and confirmed that the engine was only slightly sensitive to cold start-up with regards to all emissions. As with the 13-mode results, average transient composite emission of HC was nearly the same as with the baseline fuel, CO emission decreased slightly (2.4 percent) and NO_x increased 9.5 percent on the basis of continuous NO_x (13 percent by bag NO_x). No change in transient BSFC with the EDS blend from that obtained on the baseline fuel was noted.

Two transient test sequences were also conducted with the SRC-II blend and showed good repeatability for both HC and CO emissions. NO_x emissions were slightly more variable on this fuel. The first test indicated lower NO_x emissions from the cold-start than from the hot-start, but the second test indicated the opposite trend by both continuous and bag NO_x. The average of these two runs, given in Table 8, shows mixed cold- and hot-start NO_x emission trends for both methods of measurement. Aside from the HC emissions, the trends established from the 13-mode results parallel the average transient results. Namely, the CO increased 10 percent and the NO_x increased 21 percent over the transient baseline when SRC-II fuel blend was used. The BSFC results from both the transient and 13-mode tests indicate that a trend toward higher fuel consumption may exist with the SRC-II blend.

Using the 5 percent lube oil blend, two transient tests were conducted and showed good repeatability. The emission of NO_x by the continuous and bag methods indicated alternate trends of cold- and hot-start NO_x, mostly due to the small difference between both cold- and hot-start NO_x emissions. Similar to results from the other two alternate fuels, the trends established by the 13-mode results with the lube oil blend were maintained over the transient test. Average transient composite levels of HC increased 9 percent, CO decreased 3.6 percent and continuous NO_x increased 5.5 percent (bag NO_x increased 5.0 percent) from baseline with the lube oil blend. No change in BSFC was noted.

Two transient test sequences were also conducted with the neat soybean oil. The oil was heated at all times, even prior to "cold start-up." Problems were encountered with the soybean oil heating system after the first cold-start was completed, so an additional hot-start was run on the following day after completing the second cold- and hot-start sequence. This additional hot-start, labeled Test No. D3-38, appears as

Table E-8 in Appendix E, and the results were paired with the initial cold-start to make up a transient sequence. Total composite HC emissions were 45 percent lower with the soybean oil than with the baseline fuel. It is uncertain at this point how much of this reduction may be due to a variation in FID response to unburned soybean oil or to the filter system used. Transient composite CO emission levels were also lower with the soybean oil (9.3 percent). Perhaps the most notable change was the significant reduction in NO_x emissions over the transient test. The 23 percent lower NO_x emissions over the transient test was even more pronounced than over the 13-mode test, which had shown an 8.6 percent reduction in NO_x emissions. It is interesting that even though the continuous NO_x and bag NO_x determinations varied by almost 15 percent, both procedures indicated the same relative reduction in transient composite NO_x emissions with the soybean oil. It is suspected that most of the reduction in NO_x emissions noted for the soybean oil was due to an undetermined ignition delay effectively retarding the timing of the engine. The transient BSFC was about 14 percent greater than with the baseline fuel. Although the engine was unable to produce the rated power or torque obtained with the baseline fuel, transient statistics were quite satisfactory and the cycle power was only about 5 percent low (-15 percent is allowable) with the soybean oil.

2. Selected Individual Hydrocarbons

Some individual hydrocarbons were determined from dilute exhaust samples and processed by chromatographic techniques to separate methane, ethylene, ethane, acetylene, propylene, propane, benzene and toluene. Higher molecular weight hydrocarbons were not measured. In order to obtain proportional samples over the transient cycle, dilute exhaust samples were collected from the main tunnel of the CVS.

Results from these analyses are given in Table 9. Neither propane nor toluene were detected over the transient cycle for any of the five fuels tested. Of all the individual hydrocarbon species, ethylene, propylene, acetylene and methane were predominant. For all five fuels, "total" IHC was always higher over cold-start than over hot-start transient cycle testing. Operation with the EDS blend caused little difference in the emission of most individual hydrocarbons, although the absence of methane for the cold-start and the level detected for the hot-start are curious. Total IHC over the hot-start with the SRC-II blend was reduced primarily by the absence of propylene. Similarly, testing with the lube oil blend indicated no propylene emission during hot-start testing. Of all the fuels, the soybean oil produced the highest total of IHC with the most individual species emitted. With soybean oil, ethylene was most significant, followed by propylene, then benzene and acetylene. Aside from detecting a small amount of benzene over cold-start testing with the EDS blend, only the testing with the soybean oil showed a significant quantity of benzene emission over both cold- and hot-start transient tests.

TABLE 9. INDIVIDUAL HYDROCARBONS FROM TRANSIENT OPERATION OF THE MACK EM6-300 ENGINE WITH BASELINE AND ALTERNATE FUELS

Test Fuel	Transient Cycle	Units	Individual Hydrocarbons								IHC
			Methane	Ethylene	Ethane	Acetylene	Propane	Propylene	Benzene	Toluene	"Total"
Baseline EM-509-F	Cold Start	mg/test	91	990	0	100	0	370	0	0	1500
		mg/kW-hr	5.4	59		6.0		22			92
		mg/kg fuel	20	220		22		80			340
	Hot Start	mg/test	99	780	46	80	0	170	0	0	1200
		mg/kW-hr	6.1	48	2.9	5.0		11			73
		mg/kg fuel	23	180	11	19		40			280
25% EDS EM-515-F	Cold Start	mg/test	0	1100	0	110	0	300	79	0	1600
		mg/kW-hr		66		7.0		19	5.0		97
		mg/kg fuel		240		26		69	18		360
	Hot Start	mg/test	310	720	0	66	0	190	0	0	1300
		mg/kW-hr	19	45		4.1		12			80
		mg/kg fuel	73	170		16		45			300
25% SRC-II EM-511-F	Cold Start	mg/test	16	1000	0	120	0	310	0	0	1500
		mg/kW-hr	1.0	63		7.4		19			91
		mg/kg fuel	3.6	230		27		70			330
	Hot Start	mg/test	0	630	0	66	0	0	0	0	690
		mg/kW-hr		39		4.1					43
		mg/kg fuel		150		15					160
5% Lube Oil EM-517-F	Cold Start	mg/test	0	940	0	110	0	360	0	0	1400
		mg/kW-hr		60		7.1		23			90
		mg/kg fuel		220		26		83			330
	Hot Start	mg/test	0	750	0	85	0	0	0	0	830
		mg/kW-hr		47		5.3					52
		mg/kg fuel		180		20					200
Soybean Oil EM-510-F	Cold Start	mg/test	280	3400	83	330	0	820	430	0	5400
		mg/kW-hr	19	230	5.5	22		54	28		360
		mg/kg fuel	59	710	17	68		170	89		1100
	Hot Start	mg/test	57	1500	0	180	0	230	150	0	2100
		mg/kW-hr	3.7	96		12		15	9.4		140
		mg/kg fuel	12	320		39		49	32		450

3. Aldehydes

Aldehydes were determined by the DNPH procedure using a high-performance liquid chromatograph to detect formaldehyde, acetaldehyde, acrolein, propionaldehyde, acetone, crotonaldehyde, isobutyraldehyde, methylethylketone, hexanaldehyde, and benzaldehyde. Dilute exhaust samples were taken from the primary dilution tunnel over the 20 minute transient cycle.

Results from aldehyde analyses of these samples are given in Table 10, along with minimum detectable levels computed on the basis of baseline performance and fuel consumption. The results given in Table 10 represent the average values of replicate sample analysis (except for the cold-start with soybean oil for which one sample was voided). Some of the values given are below the minimum detectable level due to averaging. With the exception of the 5 percent lube oil blend, the total aldehydes over the cold-start transient test were significantly higher than over the hot-start transient test. Formaldehyde was most prevalent of all the individual aldehydes detected by the procedure. Although most formaldehyde was detected during cold-start operation, none was noted for the cold-start with the 5 percent lube oil blend. Considering that the hot-start accounts for 86 percent of the transient composite, total hot-start aldehydes for the EDS blend were only slightly higher than the total hot-start aldehdydes with the baseline fuel, but the cold-start aldehydes were almost twice that obtained with the baseline fuel. The total hot-start aldehydes with the soybean oil were lowest of the alternate fuels tested, due to the absence or lower concentration of most individual aldehydes; but the cold-start aldehydes were relatively high compared to the level obtained with baseline fuel. Total hot-start aldehydes with both the SRC-II blend and the 5 percent lube oil blend were essentially the same as for the baseline fuel.

4. Phenols

Phenols were determined using a wet chemistry procedure as outlined in Section III. E. 1. and described in detail in Reference 24. Dilute exhaust samples were collected over cold- and hot-start transient cycle operation. The detection of individual phenols in dilute exhaust is quite variable. The results from analysis of individual samples for phenols is given in Table 11, along with the minimum detectable level based on the performance and fuel consumption with the baseline fuel. Of the individual phenols, the group containing p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol and 2,4,6-trimethylphenol was most prevalent for all the fuels tested. This group of compounds all elute in the same region of the chromatogram and are quantified together. Phenol was detected only over the cold-start transient test with the EDS blend. Meta-cresol and para-cresol were detected over both cold- and hot-start transient operation with the SRC-II blend. The phenols emissions were low for all of the fuels tested over the transient cycle. Considering the cold- and hot-start phenol emissions on a composite basis, phenols were lowest with the baseline fuel and highest for the runs made with the EDS blend.

TABLE 10. SUMMARY OF ALDEHYDES FROM TRANSIENT OPERATION OF THE MACK EM6-300 ENGINE

Test Fuel	Transient Cycle	Units	Form-aldehyde	Acet-aldehyde	Acrolein	Propion-aldehyde	Acetone	Croton-aldehyde	Isobutyr-aldehyde	Methylethyl ketone	Benz-aldehyde	Hexan-aldehyde	Total Aldehydes
Baseline EM-509-F	Cold Start	mg/test	190	28	ND	11	ND	ND	3.9	6.0	5.5	ND	244
		mg/kW-hr	12	1.7		0.67			0.24	0.37	0.34		15.3
		mg/kg fuel	43	6.3		2.5			0.88	1.4	1.2		55.3
	Hot Start	mg/test	2.9	11	11	13	ND	8.3	12	30	11	ND	99.2
		mg/kW-hr	0.18	0.68	0.68	0.81		0.52	0.75	1.9	0.68		6.2
		mg/kg fuel	0.69	2.6	2.6	3.1		2.0	2.8	7.1	2.6		24.3
25% EDS EM-515-F	Cold Start	mg/test	450	13	ND	25	ND	ND	ND	18	60	37	603.0
		mg/kW-hr	28	0.81		1.6				1.1	3.8	2.3	37.6
		mg/kg fuel	100	3.0		5.8				4.2	14	8.6	135.6
	Hot Start	mg/test	75	ND	ND	1.8	ND	ND	1.7	9	17	ND	104.5
		mg/kW-hr	4.7			0.11			0.11	0.56	1.1		6.6
		mg/kg fuel	18			0.43			0.41	2.2	4.1		25.1
25% SRC-II EM-511-F	Cold Start	mg/test	49	ND	ND	3.6	ND	8	4.2	17	14	5.5	101.3
		mg/kW-hr	3.1			0.23		0.50	0.26	1.1	0.87	0.34	6.4
		mg/kg fuel	11			0.81		1.8	0.94	3.8	3.1	1.2	22.7
	Hot Start	mg/test	42	6	3.5	12	ND	4.1	10.3	6.5	14	ND	98.4
		mg/kW-hr	2.6	0.37	0.22	0.74		0.25	0.64	16	0.87		6.1
		mg/kg fuel	9.8	1.4	0.82	2.8		0.96	2.4	61	3.3		23.3
5% Lube Oil EM-517-F	Cold Start	mg/test	ND	6.2	7.0	12	ND	13	16	23	11	5.5	93.7
		mg/kW-hr		0.39	0.44	0.75		0.82	1.0	1.4	0.69	0.35	5.8
		mg/kg fuel		1.4	1.6	2.8		3.0	3.7	5.3	2.4	1.3	21.6
	Hot Start	mg/test	25	9.2	7.0	8.4	ND	4.2	12	14	11	5.5	96.3
		mg/kW-hr	1.6	0.57	0.44	0.52		0.26	0.75	0.87	0.69	0.34	6.0
		mg/kg fuel	6.0	2.2	1.7	2.0		1.00	2.9	3.3	2.63	1.3	23.0
Soybean Oil EM-510-F	Cold[a] Start	mg/test	400	12	7.0	4.1	ND	ND	4.8	37	22	32	518.9
		mg/kW-hr	26	0.79	0.46	0.27			0.32	2.4	1.5	2.1	33.8
		mg/kg fuel	83	2.5	1.4	0.85			0.99	7.6	4.5	6.6	107.4
	Hot Start	mg/test	ND	ND	3.5	2.1	ND	ND	4.8	33	17	16	76.4
		mg/kW-hr			0.23	0.14			0.31	2.1	1.1	1.0	4.9
		mg/kg fuel			0.76	0.45			1.0	7.1	3.7	3.4	16.4
Minimum detectable levels		mg/test	4.2	5.8	7.0	7.2	7.2	8.2	8.4	8.4	10.9	10.5	--
		mg/kW-hr	0.26	0.36	0.44	0.45	0.45	0.51	0.53	0.53	0.68	0.66	--
		mg/kg fuel	0.97	1.34	1.62	1.67	1.67	1.90	1.94	1.94	2.52	2.43	--

[a]One test only

NOTE: ND = None Detected

TABLE 11. SUMMARY OF PHENOLS FROM TRANSIENT OPERATION OF THE MACK EM6-300 ENGINE

	Transient Cycle	Units	Phenol	Salicyl-Aldehyde	M-Cresol + P-Cresol	5[a]	2.3.5 tri-Methylphenol	2.3.5.6[b]	2npp[c]	"Total" Phenols
Baseline EM-509-F	Cold Start	mg/test	ND	ND	ND	160.	16.	ND	ND	130.
		mg/kW-hr				9.4	0.93			10.
		mg/kg				34.	3.4			37.
	Hot Start	mg/test	ND	ND	ND	15.	ND	ND	ND	15.
		mg/kW-hr				0.92				0.92
		mg/kg				3.5				3.5
25% EDS EM-515-F	Cold Start	mg/test	82.	ND	ND	140.	ND	ND	ND	220.
		mg/kW-hr	5.1			8.5				14.
		mg/kg	19.			31.				50.
	Hot Start	mg/test	ND	ND	ND	130.	ND	ND	ND	130.
		mg/kW-hr				8.2				8.2
		mg/kg				31.				31.
25% SRC-II EM-511-F	Cold Start	mg/test	ND	ND	55.	57.	ND	ND	ND	110.
		mg/kW-hr			3.4	3.6				7.0
		mg/kg			12.	13.				25.
	Hot Start	mg/test	ND	ND	50.	75.	ND	ND	ND	130.
		mg/kW-hr			3.1	4.6				7.7
		mg/kg			12.	18.				30.
5% Lube Oil EM-517-F	Cold Start	mg/test	ND	ND	ND	13.	ND	ND	ND	13.
		mg/kW-hr				0.83				0.83
		mg/kg				3.0				3.0
	Hot Start	mg/test	ND	ND	ND	88.	ND	ND	ND	88.
		mg/kW-hr				5.5				5.5
		mg/kg				21.				21.
Soybean Oil EM-510-F	Cold Start	mg/test	ND	ND	ND	33.	ND	ND	ND	33.
		mg/kW-hr				2.2				2.2
		mg/kg				6.8				6.8
	Hot Start	mg/test	ND	ND	ND	76.	ND	ND	ND	76.
		mgkW-hr				4.9				4.9
		mg/kg				16.				16.
Minimum detectable level		mg/test	7.3	15.	7.3	15.	7.3	15.	15.	--
		mg/kW-hr	0.46	0.94	0.46	0.94	0.46	0.94	0.94	--
		mg/kg	1.7	3.5	1.7	3.5	1.7	3.5	3.5	--

[a] p-ethylphenol, 2-isopropylphenol, 2,3-xylenol, 3,5-xylenol, 2,4,6-trimethylphenol
[b] 2,3,5,6-tetramethylphenol
[c] 2-n-propylphenol
NOTE: ND = None Detected

5. Odor-TIA

TIA results were determined using the DOAS analysis of traps which collected compounds related to odor intensity.[25] This chromatographic procedure separates an oxygenate fraction (liquid column oxygenates, LCO) and an aromatic fraction (liquid column aromatics, LCA). The TIA values are defined as $TIA = 1 + \log_{10}$ (LCO, $\mu g/\ell$), or $TIA = 0.4 + 0.7 \log_{10}$ (LCA, $\mu g/\ell$), (TIA by LCO preferred). The procedure was developed for steady-state raw exhaust samples, but was adapted to transient dilute exhaust samples by use of the CVS. Table 12 summarizes the results from transient operation.

Results from DOAS analysis were relatively low in TIA number and were mixed, relative to cold- and hot-start trends. Comparing composite levels of TIA, a slight increase was observed with the EDS blend, whereas a decrease was noted with the SRC-II blend. No difference was noted between the TIA values derived from operation with the baseline and with the 5 percent lube oil blend. The composite TIA value with the soybean oil was slightly lower than with the baseline fuel. A definite odor of "hot cooking oil" was apparent from the CVS dilute exhaust when the engine was operated on soybean oil.

C. Particulate Emissions

Although heavy-duty diesel particulate emissions are not scheduled to be regulated until 1986, they have been measured for some time and have been recognized as a potential problem in the application of diesel engines. Particulate emissions were characterized for purposes of comparison. In order to determine particulate emission rates and to characterize the total particulate, samples were collected on several filter media for a variety of analyses which included total mass, elemental analysis, particle sizing, and organic extractables. Particulate samples were always taken from the dilute exhaust using a CVS.

1. Total Particulate

Total particulate emissions were determined over 11 modes of steady-state operation as summarized in Table 13, and their levels are illustrated graphically in Figure 7. In addition, computed 13-mode composite brake specific and fuel specific particulate emissions are given in Table 14. Recall that with the exception of 100 percent load conditions, all other modes were held to the same load as obtained with the baseline fuel. Except for operation with soybean oil, all of the particulate emissions followed the same trends, or showed the same type of curves in Figure 6. Particulate emissions with the EDS blend were generally lower than with the baseline fuel over all of the steady-state load conditions except at either of the 100 percent load conditions, resulting in 1.5 percent lower 13-mode composite brake specific particulate emission. Similarly, the SRC-II generally produced lower particulate during all load conditions other than the intermediate speed/full load condition. The 13-mode composite brake specific particulate of 0.598 g/kW-hr, with the SRC-II blend, was 4.6 percent lower

TABLE 12. SUMMARY OF TIA BY DOAS[a] FROM TRANSIENT OPERATION OF THE MACK EM6-300 ENGINE

Test Configuration	Transient Cycle	LCA µg/ℓ	LCO µg/ℓ	TIA
Baseline	Cold Start	7.74	0.90	0.95
EM-509-F	Hot Start	6.06	1.44	1.16
	Composite	6.30	1.36	1.13
25% EDS	Cold Start	26.76	3.66	1.56
EM-515-F	Hot Start	13.68	5.52	1.74
	Composite	15.55	5.25	1.71
25% SRC-II	Cold Start	0	0	0
EM-511-F	Hot Start	0.06	1.32	1.12
	Composite	0.05	1.13	0.96
5% Lube Oil	Cold Start	2.34	0	0.66[b]
EM-517-F	Hot Start	14.22	0	1.21[b]
	Composite	12.52	0	1.13[b]
Soybean Oil	Cold Start	0	4.2	1.62
EM-510-F	Hot Start	0.48	0.84	0.92
	Composite	0.41	1.32	1.02

[a]These measurements were based on diesel fuel standard. Samples were taken from dilute exhaust of approximately 6:1 for overall transient cycle.

[b]Based on $TIA_{LCA} = 0.4 + 0.7 \log LCA$

TABLE 13. PARTICULATE EMISSION SUMMARY FROM MODAL OPERATION OF THE MACK EM6-300 ENGINE

Condition rpm/load, %	Units	Test Fuel: Baseline EM-509-F	25% EDS EM-515-F	25% SRC EM-511-F	5% Lube Oil EM-517-F	Soybean EM-510-F
1260/2%	mg/m^3 exh.	63	43	53	47	76
	g/hr	22	15	18	16	26
	g/kW-hr	5.6	3.8	4.7	4.1	6.8
	g/kg fuel	6.0	4.2	5.1	4.5	7.3
1260/25%	mg/m^3 exh.	62	42	48	72	97
	g/hr	24	17	19	28	38
	g/kW-hr	0.49	0.34	0.38	0.56	0.76
	g/kg fuel	2.1	1.5	1.6	2.5	2.8
1260/50%	mg/m^3 exh.	84	60	72	89	100
	g/hr	40	29	34	41	49
	g/kW-hr	0.40	0.29	0.34	0.42	0.49
	g/kg fuel	1.9	1.4	1.6	2.0	1.9
1260/75%	mg/m^3 exh.	147	132	137	153	76
	g/hr	90	81	84	93	46
	g/kW-hr	0.60	0.54	0.56	0.63	0.31
	g/kg fuel	2.9	2.6	2.6	3.0	1.3
1260/100%	mg/m^3 exh.	201	240	232	230	98
	g/hr	153	187	175	173	66
	g/kW-hr	0.77	0.92	0.88	0.86	0.39
	g/kg fuel	3.7	4.4	4.1	4.1	1.6
Idle	mg/m^3 exh.	42	39	39	36	46
	g/hr	6.8	6.5	6.4	5.8	7.4
	g/kW-hr	--	--	--	--	--
	g/kg fuel	5.7	5.4	6.4	5.3	6.1
2100/100%	mg/m^3 exh.	82	89	78	97	53
	g/hr	109	120	104	129	65
	g/kW-hr	0.48	0.51	0.45	0.56	0.35
	g/kg fuel	2.1	2.2	1.9	2.39	1.2
2100/75%	mg/m^3 exh.	67	63	63	83	57
	g/hr	78	73	73	95	67
	g/kW-hr	0.45	0.42	0.42	0.55	0.39
	g/kg fuel	1.9	1.8	1.8	2.3	1.4
2100/50%	mg/m^3 exh.	65	63	61	81	76
	g/hr	62	61	58	78	75
	g/kW-hr	0.54	0.53	0.50	0.68	0.65
	g/kg fuel	2.0	2.1	1.9	2.6	2.2
2100/25%	mg/m^3 exh.	71	67	60	90	91
	g/hr	56	51	45	68	70
	g/kW-hr	0.96	0.88	0.78	1.2	1.2
	g/kg fuel	3.0	2.8	2.5	3.7	3.4
2100/2%	mg/m^3 exh.	44	40	41	59	75
	g/hr	27	25	24	35	46
	g/kW-hr	5.9	5.5	5.4	7.9	10
	g/kg fuel	3.1	2.9	2.8	4.1	4.8

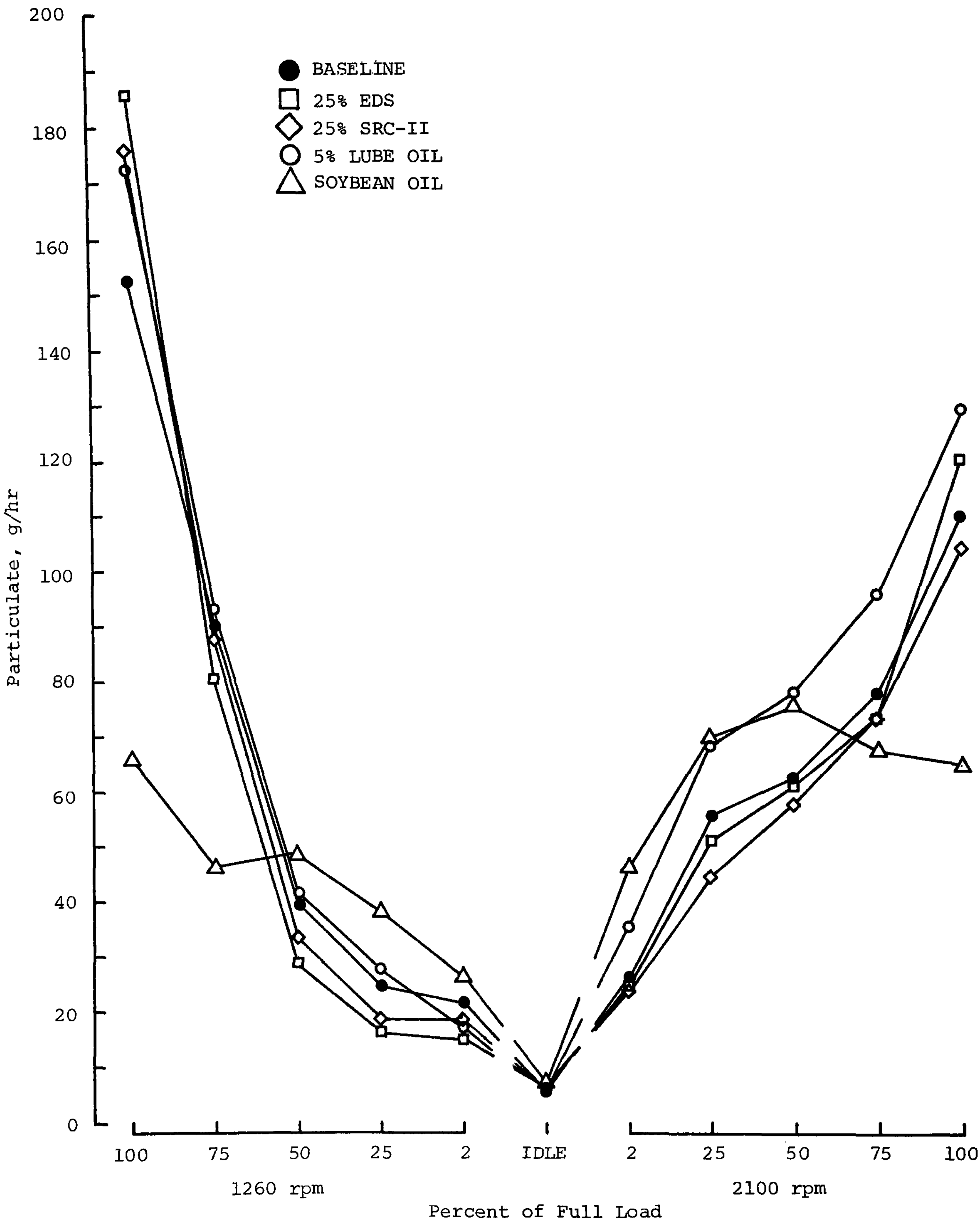

Figure 7. Modal particulate from steady-state operation of Mack EM6-300 engine with baseline and alternate fuels

TABLE 14. SUMMARY OF 13-MODE PARTICULATE FROM STEADY-STATE OPERATION OF THE MACK EM6-300 WITH VARIOUS TEST FUELS

	Computed 13-Mode Composite Particulate	
Test Fuel	Brake Specific g/kW-hr, (g/hp-hr)	Fuel Specific g/kg fuel, (g/lb fuel)
Baseline EM-509-F	0.63 (0.47)	2.59 (1.17)
25% EDS EM-515-F	0.62 (0.46)	2.57 (1.17)
25% SRC-II EM-511-F	0.60 (0.45)	2.46 (1.11)
5% Lube Oil EM-517-F	0.71 (0.53)	2.93 (1.33)
Soybean Oil EM-510-F	0.56 (0.42)	1.96 (0.89)

than with the baseline fuel. The 5 percent lube oil blend generally produced more particulate over all the steady-state conditions except idle, and resulted in a 13.5 percent higher 13-mode composite of brake specific particulate emission than with the baseline fuel. Increases in particulate with the lube oil blend were particularly noticeable during the rated speed modes.

Particulate emission results with the soybean oil were mixed. During light to medium load conditions (those at or below 50 percent), particulate emission was relatively high, mostly due to what appeared to be unburned fuel. During the idle and 2 percent load conditions a black tar-like substance leaked from the joint between the exhaust system and the turbocharger outlet. There were significant reductions of particulate emissions in both 75 percent (which were very near to 100 percent load conditions as run) and 100 percent load conditions.

By way of observation, all filter samples of particulate showed varying degrees of black to gray (ranging from high to low load conditions) discoloration of the filter. Overall filter efficiency was lowest (80 to 90 percent) during light load conditions, approaching 99 percent filter efficiency during heavy load conditions. Typically most diesel particulate samples have a distinct odor which is generally stronger from particulate samples taken at light load and idle conditions. Relative to the odor from the baseline particulate sample, the EDS and the 5 percent lube oil-derived particulate were not much different, but the SRC-II-derived particulate samples had a distinctly different odor (an odor of dust or mold). Particulate derived from the soybean oil during light loads smelled of soybean oil and the intensity diminished with increasing load. The odor from the full and 75 percent load conditions with the soybean oil were similar to those from the baseline fuel.

Particulate emissions determined for cold- and hot-start transient operation are summarized in Table 15 along with computed composite values. These results are the same as given in Table 8 along with gaseous emissions over the transient cycle. For all of the five test fuels, the cold-start had higher particulate emissions than the hot-start. This trend was most pronounced with the soybean oil. Overall, the composites of the transient-derived particulate follow the same trends established for the 13-mode composites of particulate from the various fuels. The EDS and SRC-II blends resulted in lower transient cycle particulate emissions, whereas the lube oil blend and the soybean oil resulted in higher particulate emissions, relative to particulate emissions with the baseline fuel.

TABLE 15. PARTICULATE SUMMARY FROM TRANSIENT OPERATION OF THE MACK EM6-300 ENGINE WITH VARIOUS TEST FUELS

Test	Transient Particulate, g/kW-hr		
Configuration	Cold-Start	Hot-Start	Composite
Baseline EM-509-F	0.85	0.78	0.79
25% EDS EM-515-F	0.75	0.70	0.70
25% SRC-II EM-511-F	0.76	0.66	0.67
5% Lube Oil EM-517-F	0.90	0.82	0.83
Soybean Oil EM-510-F	1.49	0.89	0.98

2. Smoke

Smoke and particulate emissions are related, smoke level being a measure of the visible portion of particulate matter. Changes in particulate emissions may be indicated by corresponding changes in smoke opacity, if the levels are high enough. Smoke opacity was determined using an end-of-stack PHS smokemeter on a 4 inch diameter exhaust stack (rated power of EM6-300 is 300 hp). Table 16 gives a summary of smoke opacity data obtained from all five fuels.

The acceleration smoke factor was above the 1980 standard (20 percent smoke opacity) for the Federal smoke test. Although adjustment to the aneroid valve could have been made, it was suggested by Mack that no adjustment should be made due to the potential for maladjustment of other factory settings. Considering the smoke opacity data obtained over 13-modes, power curve points,

TABLE 16. SUMMARY OF SMOKE OPACITY FROM THE MACK EM6-300 ENGINE

Federal Transient Smoke Cycle Opacity, %

Test Fuel	Accel.	Lug	Peak
Baseline	23.9	7.8	39.1
25% EDS	20.0	8.2	32.7
25% SRC-II	20.1	7.9	33.7
5% Lube Oil	22.4	8.1	36.6
100% Soybean	17.5	3.9	44.3
1980 Standard	20.0	15.0	50.0

Steady-State Smoke Opacity

13-Mode FTP			Smoke Opacity, %, By Fuel				
Mode	RPM	Power, %	Baseline	25% EDS	25% SRC-II	5% Lube Oil	100% Soybean
1	650	Idle	0.5	0.3	0.3	0.2	0.4
2	1260	2	0.5	0.3	0.7	0.5	0.8
3	1260	25	1.1	0.8	1.0	1.3	3.0
4	1260	50	3.2	4.5	3.0	3.8	3.4
5	1260	75	7.4	7.3	7.5	9.5	3.8
6	1260	100	10.7	10.8	12.0	12.2	4.0
7	650	Idle	0.4	0.2	0.7	0.2	0.5
8	2100	100	3.3	3.6	4.0	3.5	1.9
9	2100	75	2.4	2.4	2.9	2.8	1.6
10	2100	50	2.6	2.3	3.0	2.7	2.0
11	2100	25	3.0	2.7	3.1	3.1	2.4
12	2100	2	1.0	0.8	1.3	0.9	2.1
13	650	Idle	0.5	0.4	1.0	0.2	1.3

Power Curve Smoke Opacity

	Power Curve Smoke Opacity, %, By Fuel				
RPM	Baseline	25% EDS	25% SRC-II	5% Lube Oil	100% Soybean
2100	3.5	3.4	3.8	3.2	1.0
1900	2.9	3.0	2.6	3.0	0.7
1700	3.4	3.2	3.0	3.2	0.9
1500	4.8	4.7	4.4	4.8	1.3
1260	9.8	11.0	11.0	12.0	3.5
1000	28.0	27.0	25.5	31.0	13.5

and the Federal smoke cycle with the baseline fuel, the EDS blend indicated a trend to lower smoke opacities except during high load steady-state conditions. The EDS blend also tended to yield lower acceleration and peak factors. Smoke opacities with the SRC-II blend were almost the same as with the EDS blend, but most steady-state conditions yielded slightly higher opacity levels. Percent smoke opacities over the Federal smoke test with the SRC-II produced lower acceleration and peak factors, while no significant change was noted in the lug factor. The 5 percent lube oil had been reported to reduce smoke opacities from some naturally aspirated engines, but had no effect on smoke for turbocharged engines.[30] The results over both 13-mode and power curve runs with the 5 percent lube oil blend indicated a trend to higher levels of smoke opacity for this turbocharged engine. Over the Federal smoke cycle, the acceleration and peak factors were below the baseline, but the lug factor indicated a higher smoke opacity. Results from operation with neat soybean oil were quite surprising. Based on the relatively high smoke opacities observed during light load conditions, one might expect very high opacities during high load conditions. Instead, smoke opacities above the 25 percent load condition were significantly lower, especially over the power curve operating range. Although the lug smoke factor was very low and the acceleration factor was also reduced with the soybean oil, the peak factor increased substantially.

3. Sulfate

Sulfate was determined from samples of total particulate collected on 47 mm Fluoropore filter media, and processed by the BCA method. Results of sulfate analysis of total particulate samples acquired over cold- and hot-start transient operation are given in Table 17. Since the sulfate originates from sulfur contained in the fuel, additional sulfate emissions were computed in terms of mg/kg of fuel. A percent of fuel sulfur converted to sulfate was also computed, and reflects the tendency of the engine-fuel combination to convert fuel sulfur to sulfate.

Except for the soybean oil, which contained <u>no</u> sulfur, the remaining test fuels all contained some sulfur. The results indicated a significant cold- and hot-start dependence for sulfate emissions. Cold-start sulfate was nearly double that of the hot-start levels. Relative to the baseline levels, composite brake specific sulfate levels decreased 27 percent with EDS, increased 32 percent with the SRC-II and increased 46 percent with the lube oil blend. The same trends were also noted for the percent of fuel sulfur converted to sulfate.

TABLE 17. SULFATE EMISSION SUMMARY FROM TRANSIENT FTP OPERATION OF THE MACK EM6-300 ENGINE WITH BASELINE AND ALTERNATE FUELS

	Transient Cycle	Sulfate Rate mg/test	Sulfate Rate mg/kW-hr	Sulfate Rate mg/kg fuel	%of Fuel S in $SO_4^=$
Baseline EM-509-F	Cold	1080	67	250	3.6
	Hot	510	32	120	1.7
	Composite	590	37	140	2.0
25% EDS EM-515-F	Cold	740	46	170	3.1
	Hot	380	24	92	1.7
	Composite	430	27	100	1.9
25% SRC-II EM-511-F	Cold	1300	83	300	3.7
	Hot	690	43	160	2.0
	Composite	780	49	180	2.2
5% Lube Oil EM-517-F	Cold	1200	75	270	3.8
	Hot	820	51	190	2.6
	Composite	870	54	200	2.8
Soybean Oil EM-510-F	Cold	0	0	0	-
	Hot	0	0	0	-
	Composite	0	0	0	-

4. Elemental Composition

Elemental analysis of the total particulate required two particulate samples. The carbon and hydrogen contents of the total particulate were determined from particulate samples collected on glass fiber filter media by oxidation techniques. Sulfur and metal content were determined from particulate samples collected on Teflon membrane filter media (Fluoropore) using x-ray fluorescence techniques. The carbon and hydrogen were determined by Galbraith Laboratories, and the sulfur and metals were determined by EPA-RTP.

A summary of elemental analysis is given in Table 18. Relative to the total particulate obtained for transient testing with the baseline fuel, the percent carbon and hydrogen tended to be lower with the SRC-II blend but higher with the soybean oil. Relative to baseline particulate, the EDS blend-derived particulate had notably lower concentrations of sulfur and iron, as well as a lower percentage of other metals. With use of the SRC-II blend, lower portions of carbon, but significantly higher portions of sulfur were noted.

Although the 5 percent lube oil blend caused insignificant changes in the relative portion of carbon and hydrogen in the particulate, the per-

TABLE 18. SUMMARY OF ELEMENTAL ANALYSIS OF TOTAL PARTICULATE FROM TRANSIENT OPERATION OF MACK EM6-300 WITH BASELINE AND ALTERNATE FUELS

Fuel	Cycle Type	Element, Percent by Weight of Total Particulate																	
		C	H	S	Cl	Si	Ca	Na	Mg	Al	P	K	Ti	Mn	Fe	Cu	Zn	Sn	Sb
Baseline	Cold	71.2	3.1	1.9	0.02	0.05	0.32	a	b	0.07	0.16	b	a	b	3.5	a	0.22	0.03	b
EM-509-F	Hot	71.0	2.9	1.6	a	a	0.04	a	a	a	0.05	a	a	a	0.32	a	b	a	a
25% EDS	Cold	74.3	3.1	1.4	a	0.06	0.15	a	a	0.07	0.10	a	a	a	b	a	b	b	a
EM-515-F	Hot	68.0	2.6	1.3	a	0.05	0.10	a	b	b	0.06	a	a	a	0.18	a	b	b	a
25% SRC-II	Cold	64.1	2.4	2.3	b	b	0.37	a	b	0.04	0.19	b	a	b	1.9	b	0.32	0.04	b
EM-511-F	Hot	65.9	3.1	2.5	a	a	0.07	a	a	a	0.09	a	a	a	0.29	b	b	b	b
5% Lube Oil	Cold	71.8	2.8	1.9	0.16	0.10	1.1	b	1.5	b	1.8	a	a	a	1.1	b	2.0	b	b
EM-517-F	Hot	68.3	2.4	1.6	0.16	0.66	0.88	b	1.3	b	1.5	a	a	a	0.49	a	1.7	0.04	b
Soybean Oil	Cold	73.6	7.5	b	b	a	b	a	a	a	a	b	a	a	a	a	a	b	b
EM-510-F	Hot	78.1	7.1	b	b	b	a	a	a	a	b	a	b	a	a	a	a	b	a

[a] Not detected
[b] Detected but level was below limit of quantification

centage and the variety of metals found in the total particulate were significantly increased. No change in sulfur was noted, but significantly higher portions of Si, Ca, Mg, P and Zn were noted with the lube oil blend. The presence of these elements is attributed to wear metals and additives found in used crankcase oil. Total particulate from transient operation with soybean oil showed the highest portion of carbon and hydrogen, which implies that the total particulate was oily in nature, likely a result of unburned fuel. For the soybean oil-derived particulate, no metals or other elements were concentrated enough to quantify.

5. Particle Size Distribution

Particle sizing by the Sierra Model 220 cascade impactor was used to obtain a particle size distribution from transient FTP operation. The impactor was positioned inside the primary tunnel operated with a CVS flow rate of 5000 cfm. Separate impactor disc sets were used for the individual cold-start and the hot-start transient tests run with each fuel.

The individual particle distribution plots from the indivudual cold- and hot-start transient tests with each fuel are given as a figure in each of the corresponding Appendices. The composite results from each of these plots are given in Figure 8. With the baseline fuel, about 70 weight percent of the particulate was less than 0.1 micron Effective Cut-off Diameter (ECD). Approximately 90 percent was less than 1.0 micron ECD, and about 98 percent was less than 6.0 microns. The particle size distribution with the EDS, lube oil and the soybean oil are essentially the same as obtained with the baseline fuel. Only the SRC-II blend indicated a shift to larger particles. (Information for 0.1 micron ECD was void due to loading error of last collection plate in front of the back-up filter). Approximately 79 percent of the SRC-II-derived particulate was less than 1.0 micron ECD.

6. Soluble Organic Fraction

The soluble organic fraction (SOF) of the total particulate was obtained from particulate samples collected on Pallflex filter media using soxhlet extraction procedures with methylene chloride. The SOF has been reported as a percentage of the total particulate, and is often referred to as percent solubles. This result gives an indication as to the nature of the total particulate matter, but makes it difficult to compare SOF emission rates obtained with the various test fuels. Table 19 summarizes the SOF mass emissions and percent solubles from transient operation with each of the five fuels.

Sensitivity of SOF emissions to cold starts appears to be mixed for the various fuels. Comparing transient composite values, the brake specific SOF emission with the EDS blend and lube oil were about the same as with the baseline fuel. Transient composite brake specific SOF increased about 15 percent with the SRC-II, and increased to about 4.5 times the baseline level with the soybean oil.

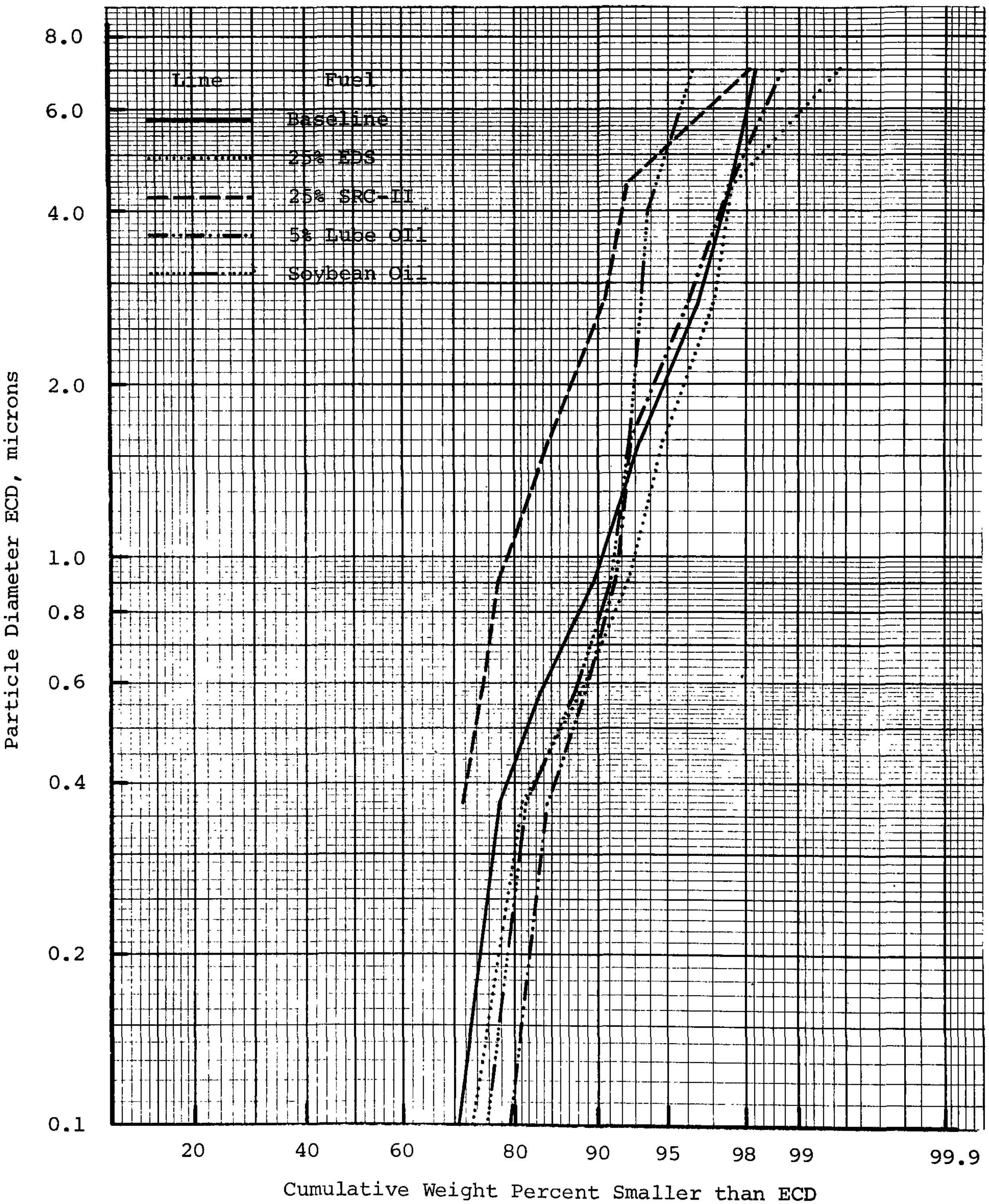

Figure 8. Composite of transient particle size distribution from the Mack EM6-300 with baseline and alternate fuels

TABLE 19. SUMMARY OF SOLUBLES IN TOTAL PARTICULATE

Fuel	Percent Solubles in Total Particulate and (Solubles Emission Rate (g/kW-hr))		
	Cold Start	Hot Start	Composite[a]
Baseline EM-509-F	15.9 (0.14)	16.3 (0.13)	16.2 (0.13)
25% EDS EM-515-F	20.9 (0.16)	19.1 (0.13)	19.4 (0.14)
25% SRC-II EM-511-F	16.0 (0.12)	23.0 (0.15)	22.0 (0.15)
5% Lube Oil EM-517-F	13.6 (0.12)	16.2 (0.13)	15.8 (0.13)
Soybean Oil EM-510-F	73.0 (1.09)	56.2 (0.50)	58.6 (0.57)

[a] Calculated

The SOF was also determined over 11 modes of steady-state operation, and is given in Table 20, along with 13-mode composite SOF emission levels (idle weighted 20 percent). The greatest percentages of extractables were noted for the idle and the 2 percent load conditions, where typically more unburned fuel is emitted. Comparing 13-mode composite SOF emission rates, there was little difference between the baseline fuel and the EDS, SRC-II and 5 percent lube oil blends. The 13-mode composite SOF emission with the soybean oil was almost twice that of the baseline composite SOF emission level. Most of this increase in SOF emission was due to the relatively large portion of solubles emitted during the steady-state rated speed conditions where the percent of SOF was approximately 55 percent over the entire load range.

TABLE 20. SUMMARY OF SOLUBLE ORGANIC FRACTION FROM STEADY-STATE OPERATION OF THE MACK EM6-300 WITH BASELINE AND ALTERNATE FUELS

Steady-State Condition rpm/load	Percent Solubles in Total Particulate and (Soluble Particulate Rate (g/hr))				
	Baseline EM-509-F	25% EDS EM-515-F	25% SRC-II EM-511-F	5% Lube Oil EM-517-F	Soybean Oil EM-510-F
1260/2	80 (18)	79 (12)	59 (11)	61 (9.8)	80 (21)
1260/25	62 (15)	73 (12)	82 (16)	42 (12)	58 (22)
1260/50	23 (9.2)	30 (8.7)	26 (8.8)	21 (8.6)	37 (18)
1260/75	9 (8.1)	15 (12)	5 (4.2)	12 (11)	10 (4.6)
1260/100	13 (20)	9 (17)	12 (21)	13 (22)	12 (7.9)
Idle	77 (5.2)	86 (5.6)	90 (5.8)	74 (4.3)	83 (6.1)
2100/100	11 (12)	21 (25)	16 (17)	13 (17)	51 (33)
2100/75	15 (12)	22 (16)	21 (15)	18 (17)	53 (36)
2100/50	17 (11)	24 (15)	22 (13)	17 (13)	58 (44)
2100/25	20 (11)	25 (13)	22 (9.9)	20 (14)	53 (37)
2100/2	62 (17)	85 (21)	77 (18)	49 (17)	71 (33)

Units	13-Mode Composite Emission of Soluble Particulate				
g/kw-hr	0.14	0.15	0.14	0.14	0.27
g/kg fuel	0.56	0.63	0.56	0.57	0.94

a. Benzo(a)pyrene

Benzo(a)pyrene (BaP) content was determined for SOF extracted from total particulate samples obtained over both cold- and hot-start transient testing, using methylene chloride as the solvent. Results from analysis for BaP are given in Table 21. In all cases, the cold-start brake specific emission

TABLE 21. SUMMARY OF BENZO(A)PYRENE EMISSIONS FROM TRANSIENT OPERATION OF THE MACK EM6-300 WITH BASELINE AND ALTERNATE FUELS

Fuel	Cycle Type	Benzo(a)pyrene Emissions		
		μg BaP/mg SOF	μg BaP/kW-hr	μg BaP/kg fuel
Baseline	Cold	0.0032	0.45	1.7
EM-509-F	Hot	0.00050	0.065	0.25
25% EDS	Cold	0.013	2.1	7.8
EM-515-F	Hot	0.0028	0.36	1.4
25% SRC-II	Cold	0.015	1.8	6.5
EM-511-F	Hot	0.0018	0.27	1.0
5% Lube Oil	Cold	0.0038	0.46	1.7
EM-517-F	Hot	0.0024	0.31	1.2
Soybean Oil	Cold	0.10	11.	35.
EM-510-F	Hot	0.0071	3.6	12.

of BaP was greater than that for the hot-start transient test. The lowest BaP emission (0.065 μg BaP/kW-hr) was noted for the hot-start transient with baseline fuel, and the highest (11. μg BaP/kW-hr) was noted for the cold-start transient with soybean oil. The lube oil blend gave nearly the same cold-start brake specific BaP level as obtained on baseline fuel, but the hot-start was almost five times higher. The brake specific emission of BaP over hot-start transient testing was about the same for the EDS, SRC-II and lube oil blends. The brake specific BaP emission for the hot-start transient testing with the soybean oil was nearly 55 times that obtained on the baseline fuel. This high emission of BaP with soybean oil was surprising, and was verified by doping the test sample with a standard solution.

b. Boiling Point Distribution

A high-temperature GC-simulated boiling point distribution with internal standard (C_9-C_{11}) was conducted on SOF from cold- and hot-start transient operation of the Mack EM6-300 with baseline and the alternate fuels. The numerical results of these analyses are presented in Table 22. The

TABLE 22. BOILING POINT DISTRIBUTION OF SOLUBLE ORGANIC FARCTION FROM TRANSIENT OPERATION OF THE MACK EM6-300 WITH BASELINE AND ALTERNATE FUELS

Distillation Point	Boiling Temperature at Distillation Point, °C									
	Baseline		25% EDS		25% SRC-II		5% Lube Oil		Soybean Oil	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
IBP	289	301	307	297	276	270	290	311	297	292
10% point	381	374	383	377	384	373	378	383	434	394
20% point	400	392	398	394	408	391	400	403	548	425
30% point	418	408	412	407	435	405	418	423		468
40% point	443	428	429	422	477	419	440	445		541
50% point	482	457	449	442		436	470	480		
60% point		534	483	471		458	532	582		
70% point				557		496				
80% point										
90% point										
EP										
Recovery, % @ 582°C	59	62	69	72	47	78	64	60	22	44

resulting chromatograms from these analyses are given in the appendices of the corresponding fuels (Baseline - Figures A-2 and A-3; EDS - Figures B-2 and B-3; SRC-II - Figures C-2 and C-3; Lube Oil - Figures D-2 and D-3; Soybean Oil - Figures E-2 and E-3).

Besides the peaks representing the solvent (methylene chloride) and the internal standards (C_9-C_{11}), all of the chromatograms showed a maximum peak around 22 minutes into the run which coincides with hydrocarbon compound standards that boil between 391 and 431°C and contain 24 to 28 carbon atoms, respectively. All the samples showed relatively high levels of "residue"; that is, none of the samples could be completely volatilized below 582°C, which was the maximum column equivalent temperature reached during the procedure. The cold-start generally had lower recovery (higher "residue") than hot-start-derived particulate extracts. The boiling point distribution for the cold-start-derived SOF with the lube oil blend fuel was very similar to that of the cold-start-derived SOF with the baseline fuel. The boiling point distribution of the SOF derived from combustion of soybean oil indicated that substantial portions of the extract had boiling points above 582°C, particularly for the cold-start when most of the extract is likely composed of unburned soybean oil.

c. Fractionation by Relative Polarity

The composition of the soluble organic fraction of the total particulate is complex, and its separation into individual compounds is very difficult. Fractionation of the SOF by high performance liquid chromatography (HPLC) separated the soluble portion into a series of fractions of increasing molecular polarity. Figures 9 through 18 show the HPLC chromatographic outputs for direct comparison of the relative concentration of increasingly polar compounds from both cold- and hot-start transient operation of the Mack EM6-300 engine with baseline and alternate fuels.

Each figure contains two traces, one representing the fluorescence detector response, and the other representing the ultraviolet detector response. The fluorescence trace starts at time 0. The ultraviolet trace is scale offset by about 1 minute due to pen offset of the recorder. Initially, the solvent is composed of 95 percent hexane and 5 percent methylene chloride, a relatively non-polar mixture. This solvent mixture is used from the start of the chromatogram to 17 minutes into the elution period (designated by "^"). During this period, non-polar PNA compounds elute and give untraviolet and fluorescence responses. BaP elutes around 12 minutes. After 17 minutes, the polarity of the solvent is increased at a rate of 5 percent methylene chloride per minute. During this transition period of solvent polarity, increasingly polar compounds are eluted, giving fluorescence and ultraviolet spectra. At the end of this solvent transition period (36 minutes into the run and designated by "^"), the solvent is 100 percent methylene chloride. With 100 percent methylene chloride, even more polar compounds elute. The compound 9-fluorenone elutes around 37 minutes, and acridine elutes at about 70 minutes (in the polar period).

Figures 9 and 10 show the HPLC response to the SOF derived from cold- and hot-start transient operation with baseline fuel. The chromatograms from both cold- and hot-start were very similar. Both chromatograms indicate the presence of non-polar compounds at about 3 and 10 minutes elution time by definite ultraviolet response, possibly due to BaP. In the transition region, there were two fluorescence peaks, one around 25 and the other around 34 minutes. In the polar region, a compound such as 9-fluorenone is indicated by the ultraviolet peak at 37 minutes. Another ultraviolet peak was prominent at approximately 40 minutes, but this peak has been noted before due to an unknown column contaminant and may be difficult to attribute to the SOF samples alone. A selectively strong fluorescence peak around 46 minutes also appeared in the polar region, but its origin is not known.

Figures 11 and 12 show the HPLC response to SOF derived from cold- and hot-start transient operation with the EDS blend. Both chromatograms were similar to those with the baseline fuel, except for an additional peak of ultraviolet response in the non-polar region for the hot-start-derived SOF. In addition, both ultraviolet and fluorescence response for the BaP region (12 minutes) appears to be more defined for the cold-start SOF with the EDS blend than noted for the baseline fuel.

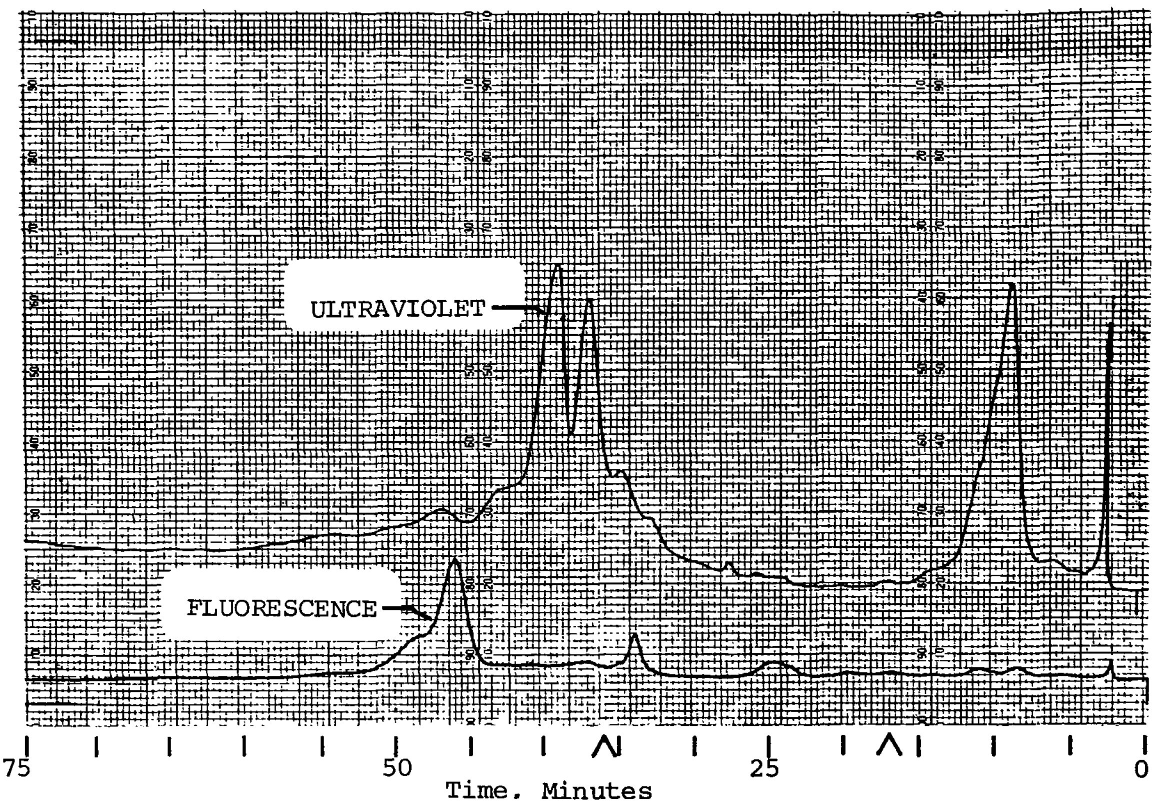

Figure 9. HPLC response to SOF from cold transient with baseline fuel

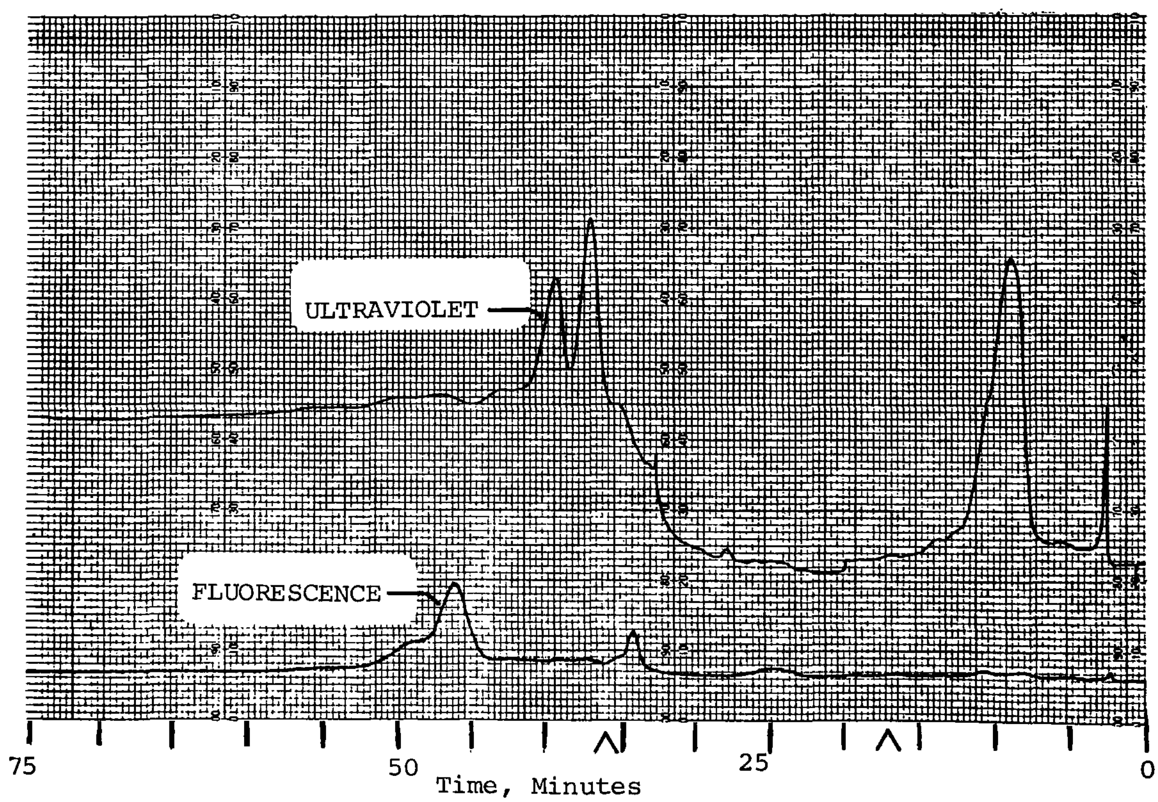

Figure 10. HPLC response to SOF from hot transient with baseline fuel

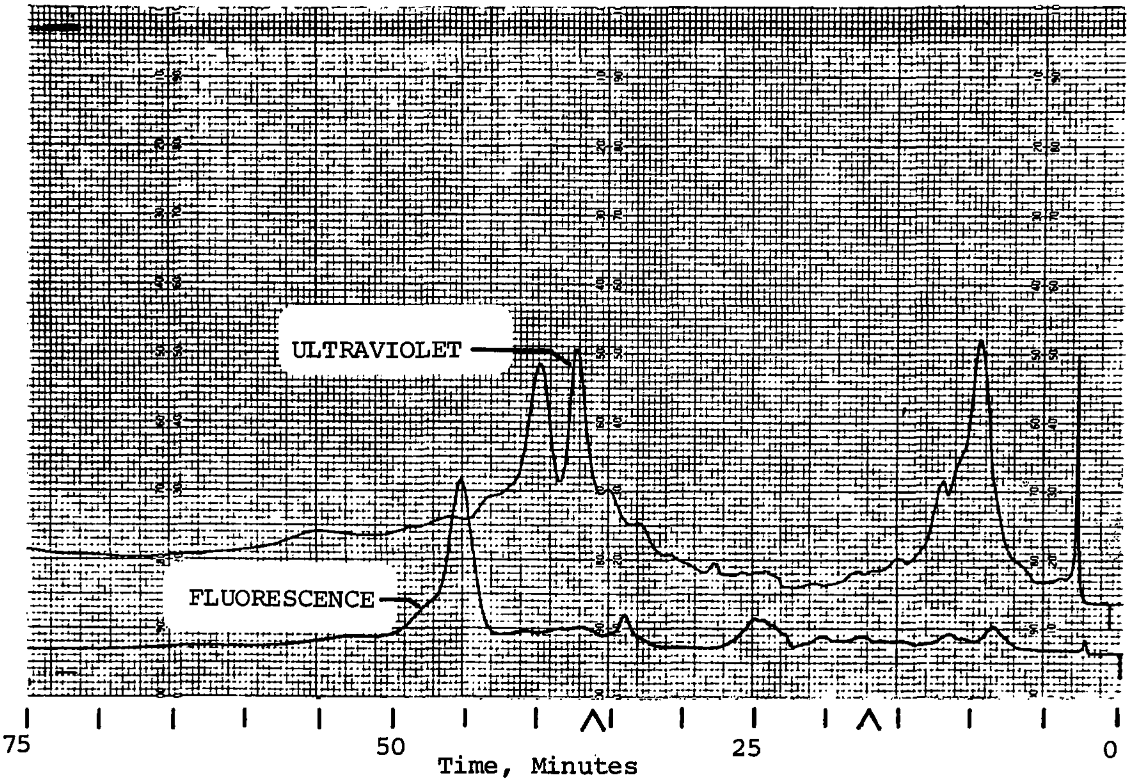

Figure 11. HPLC response to SOF from cold transient with EDS blend

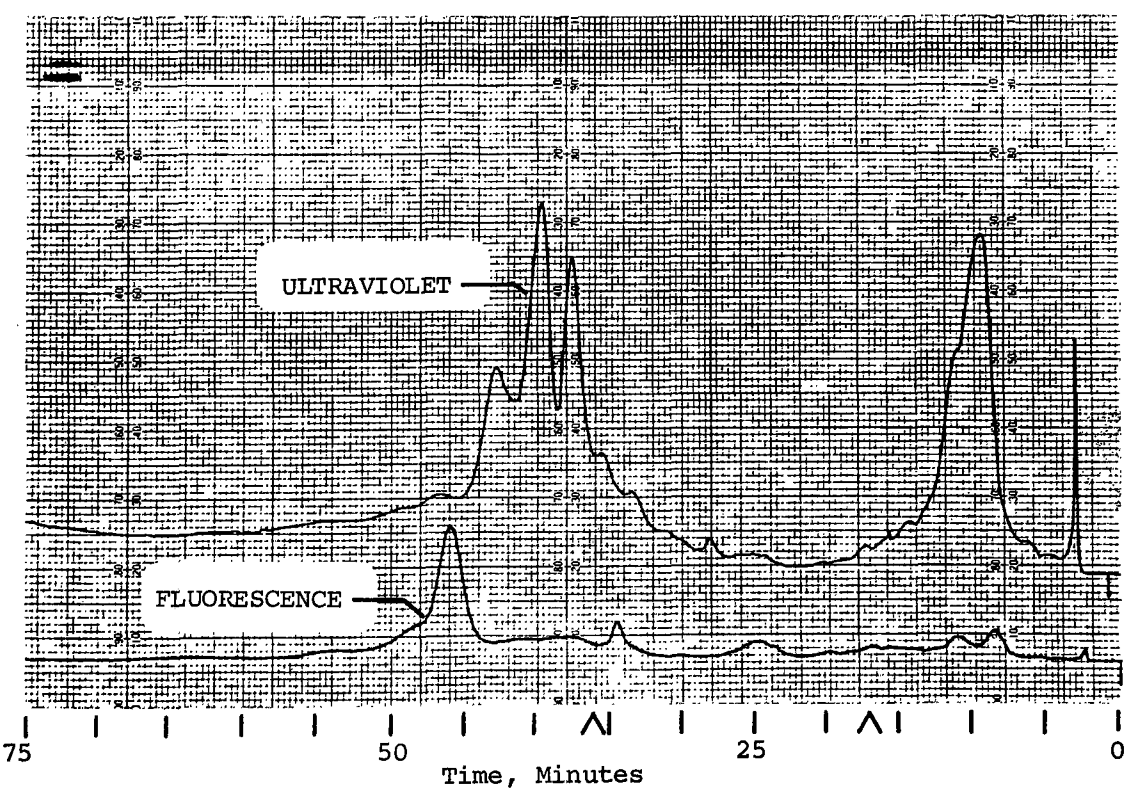

Figure 12. HPLC response to SOF from hot transient with EDS blend

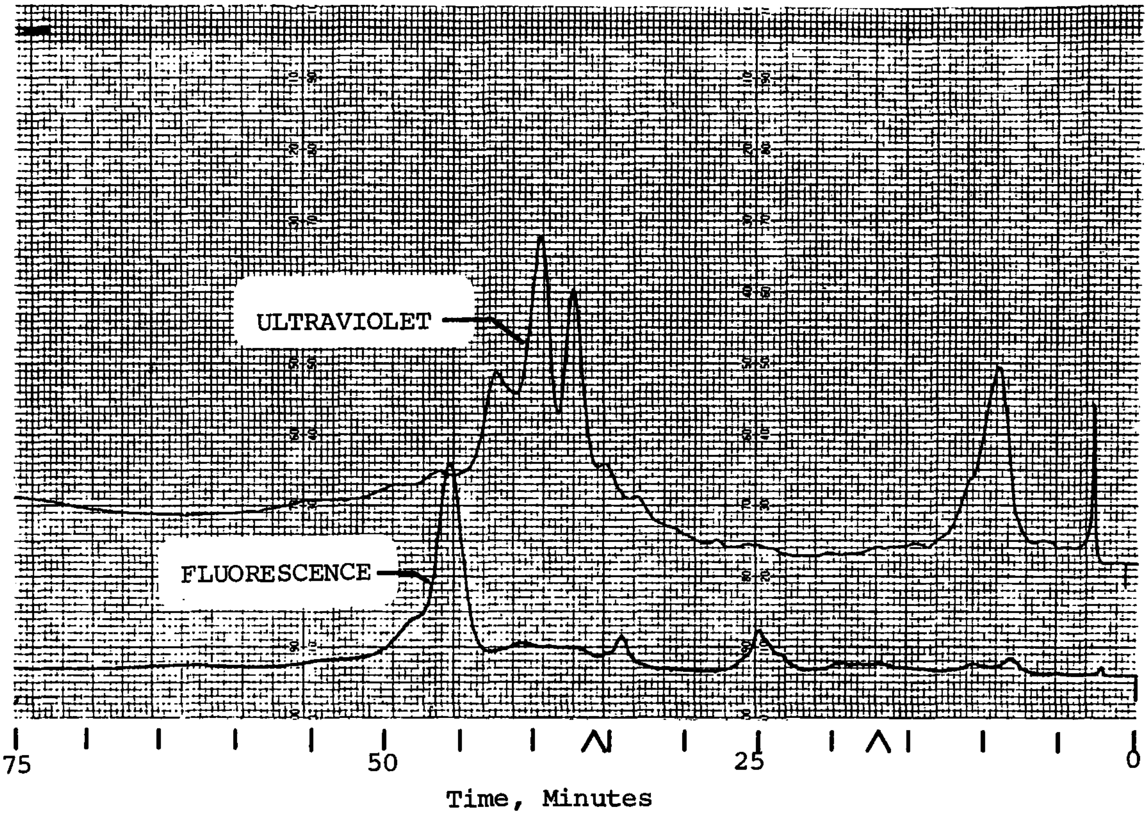

Figure 13. HPLC response to SOF from cold transient with SRC-II blend

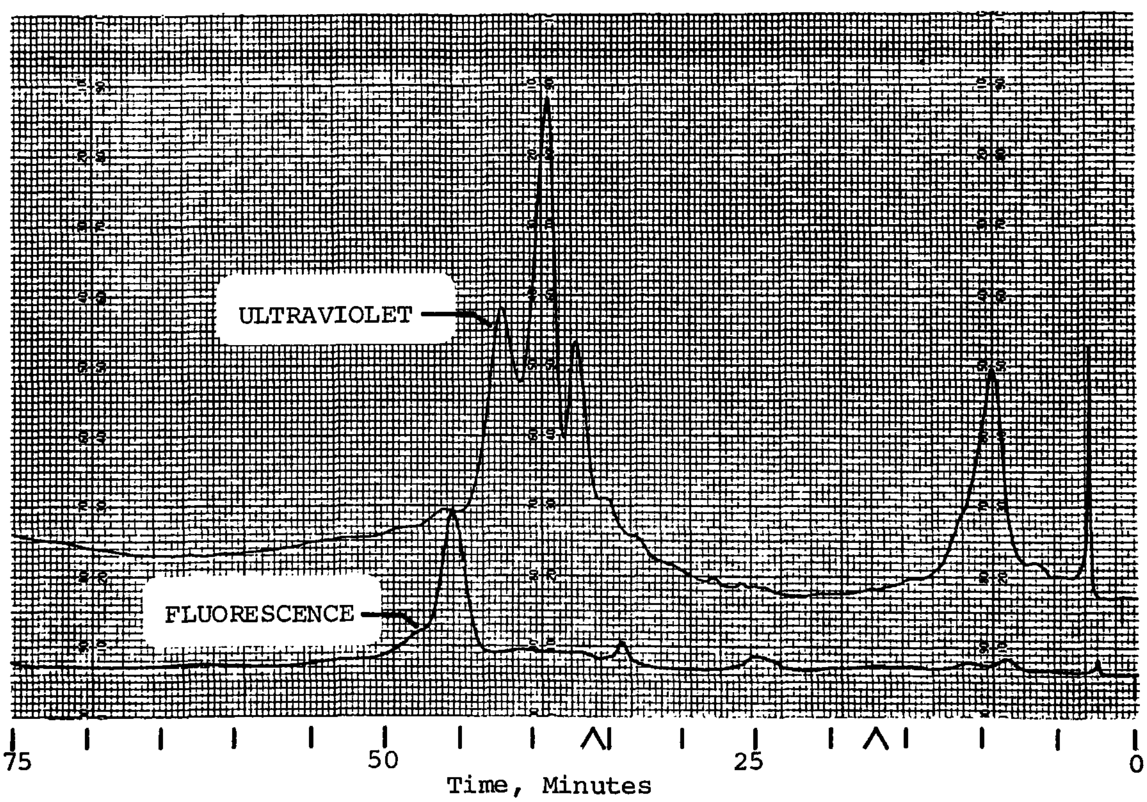

Figure 14. HPLC response to SOF from hot transient with SRC-II blend

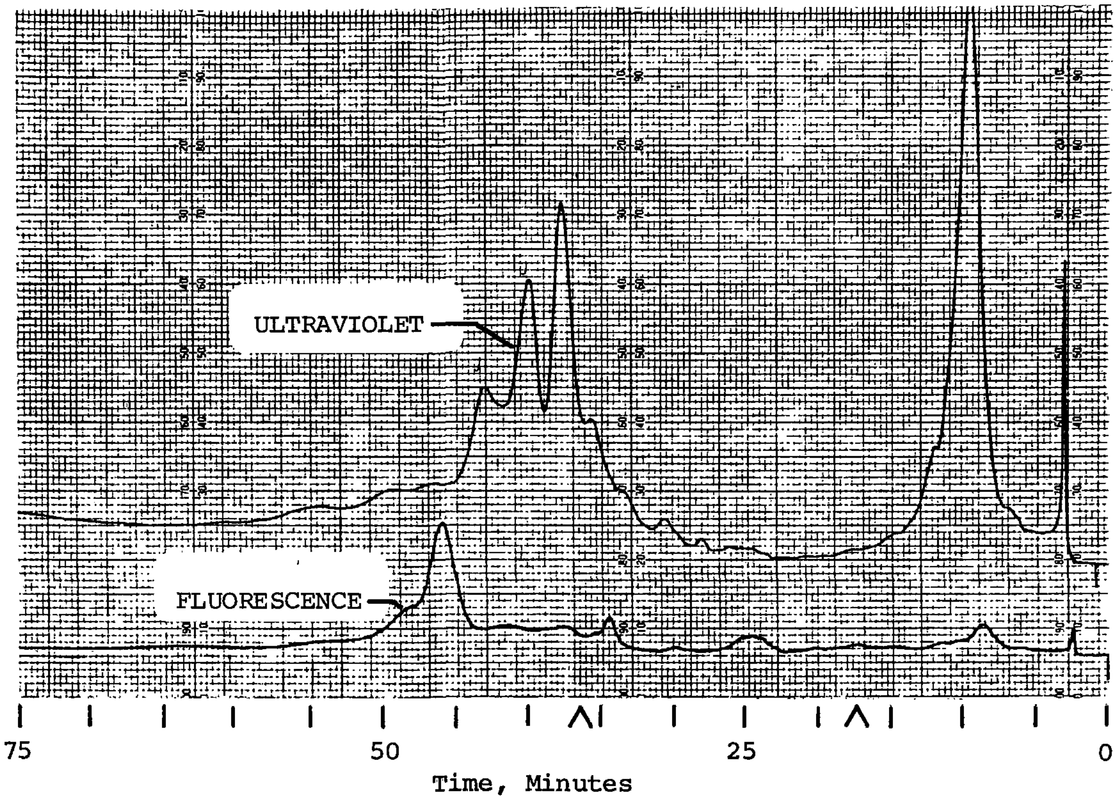

Figure 15. HPLC response to SOF from cold transient with Lube Oil blend

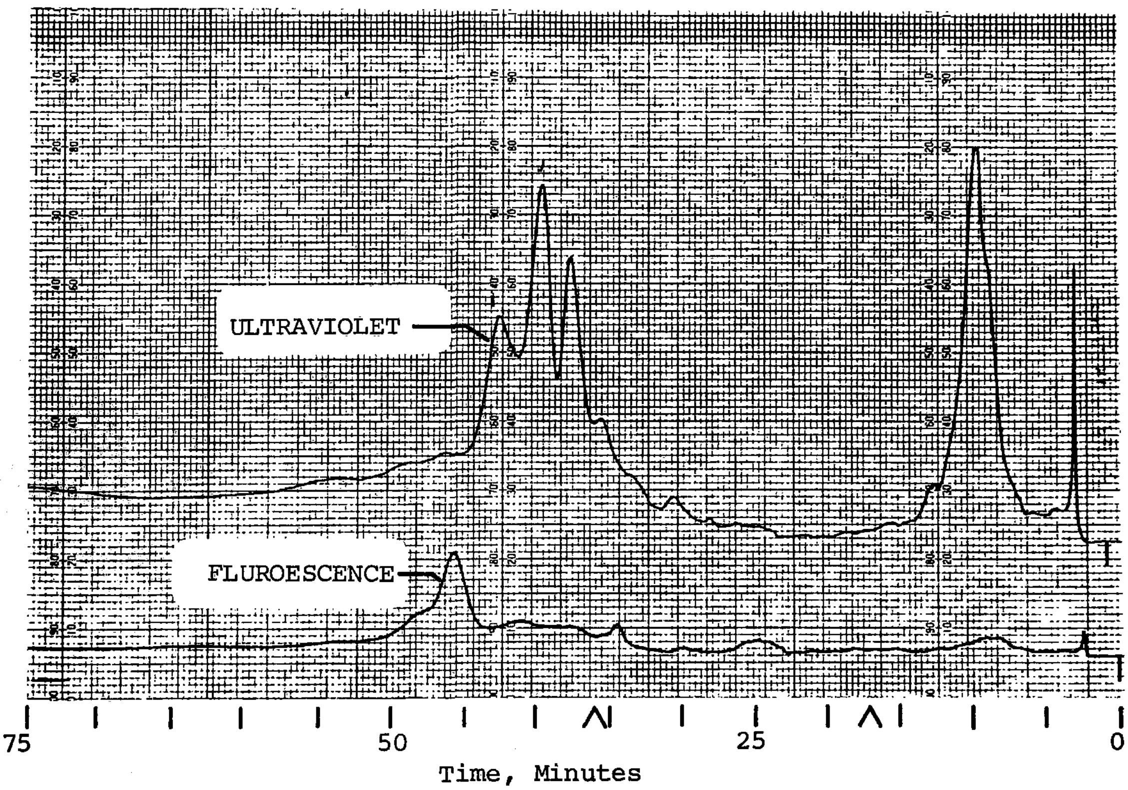

Figure 16. HPLC response to SOF from hot transient with Lube Oil blend

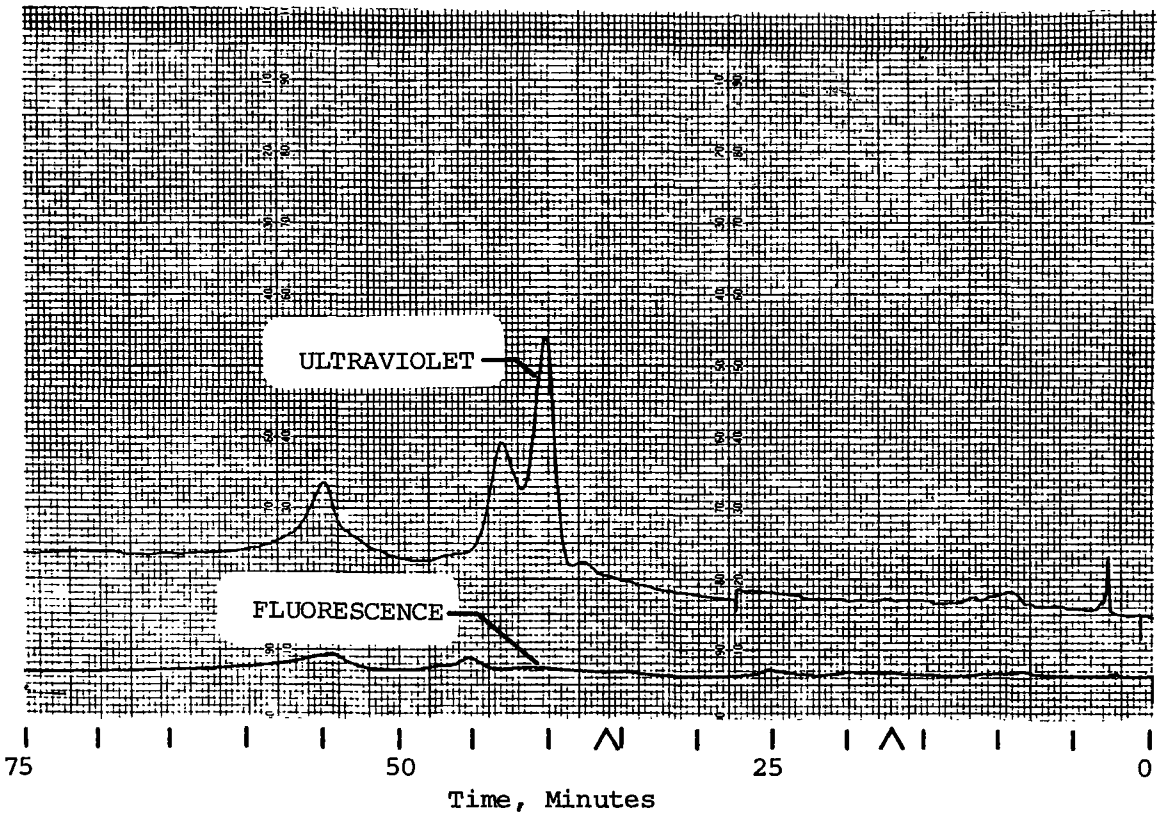

Figure 17. HPLC response to SOF from cold transient with soybean oil

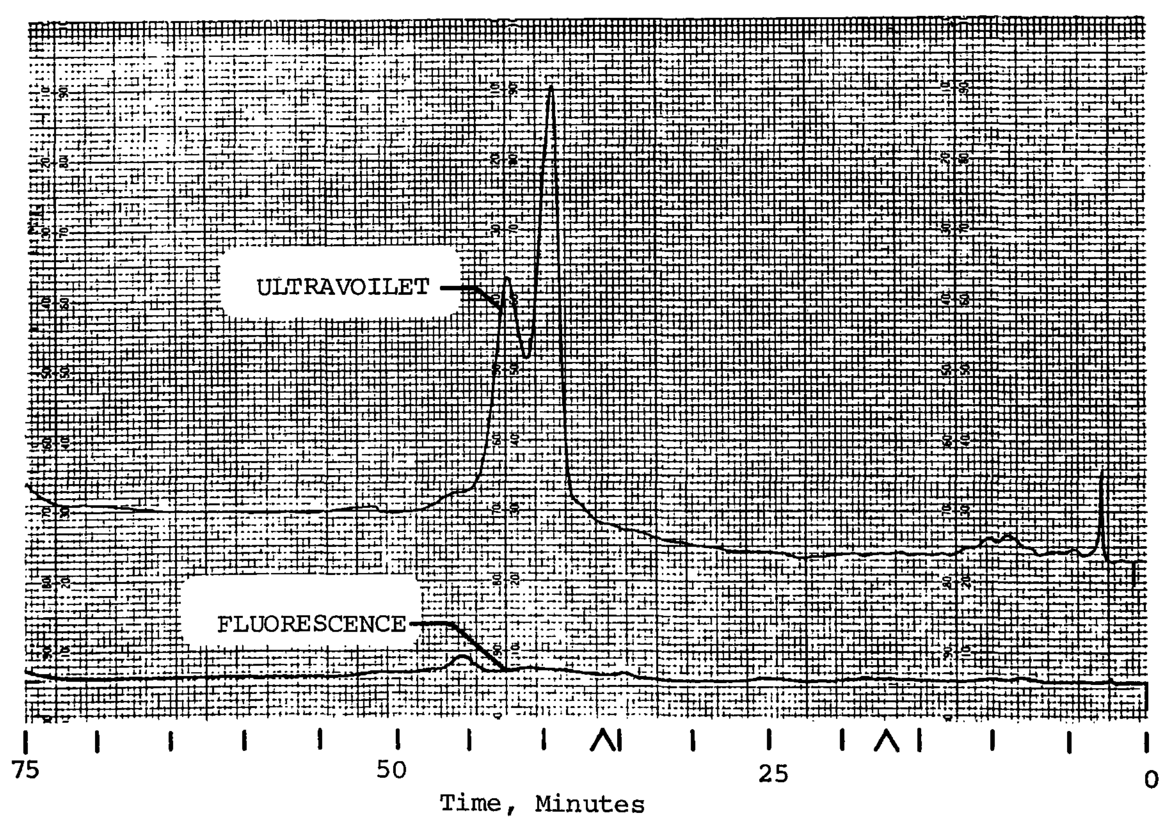

Figure 18. HPLC response to SOF from hot transient with soybean oil

Figures 13 and 14 show the HPLC response to SOF from cold- and hot-start transient operation with the SRC-II blend. As with the baseline fuel, both cold- and hot-start chromatograms with the SRC-II fuel were quite similar to one another. These chromatograms were similar to that from the hot-start with the EDS blend, especially with regards to the presence of the ultraviolet peak around 40 minutes and the fluorescence peak around 46 minutes, particularly for the hot-start SOF.

Figures 15 and 16 show the HPLC response to SOF from cold- and hot-start transient operation with the 5 percent lube oil fuel blend. In general, the chromatograms are also quite similar to those obtained with the baseline fuel, EDS and SRC-II blends. However, the ultraviolet response around 10 minutes, which includes BaP (at 12 minutes), is noticeably greater for both the cold- and hot-start with 5 percent lube oil. The ultraviolet peak at 42 minutes is present, as it was for the EDS and SRC-II blends, but not for the baseline fuel. The fluorescence response is very near that obtained for the baseline fuel.

Figures 17 and 18 show the HPLC response to the SOF derived from cold- and hot-start transient operation with the neat soybean oil. Both chromatograms are similar to one another, except that the cold-start chromatogram contains an ultraviolet and a small fluorescence peak around 55 minutes (well into the non-polar region). Relative to the response for the baseline fuel, hardly any ultraviolet response was noted in the non-polar region, even though the level of BaP emission was highest with the soybean oil. Although this would appear to be an anomaly, it should be noted that BaP is not well defined by any of the chromatograms for any of the test fuels. When BaP is included in a standard, it has a response which includes both ultraviolet and fluorescence. This combined response was not noted for any of the HPLC chromatograms discussed here, and it is likely that the procedure is not sensitive enough to indicate low concentrations of BaP. The soybean oil HPLC chromatograms also have two ultraviolet peaks which appear to be similar to the baseline chromatograms. These peaks occur at 40 and 43 minutes whereas the two ultraviolet peaks for the baseline fuel occurred at 37 and 40 minutes. Except as already noted, the fluorescence response was minimal.

d. Ames Response

The Ames test, as employed in this program, refers to a bacterial mutagenesis plate assay with Salmonella typhimurium according to the method of Ames.[28] This bioassay determines the ability of chemical compounds or mixtures to cause mutation of DNA in the bacteria, positive results occurring when histidine-dependent strains of bacteria revert (or are mutated) genetically to forms which can synthesize histidine on their own. Samples of the soluble organic fraction representing transient composites were submitted for bioassay over five tester strains (TA1535, TA1537, TA1538, TA89, and TA100), with and without metabolic activation.

Results from Ames testing are given in Table 23, and include the slope of dose response, which represents the statistically determined slope of the function representing revertants per plate versus micrograms SOF dosage. This result is termed "specific activity," and is an indication of the level of mutagenic potential of the extract. Results are also given in terms of brake specific response, which represents the specific activity multiplied by the SOF brake specific emission rate. The units for the brake specific response are then

$$\frac{\text{million revertants/plate}}{\text{kW-hr}}$$

The "million revertants per plate" per "kW-hr" is useful for comparison purposes, but has no practical meaning. Samples from the first group were tested twice over a period of one to three weeks. The specific activities from these replicate tests are given in Table 23 under the headings, "Test 1" and "Test 2." The average of these specific activities was used in conjunction with the brake specific emission of SOF to calculate the brake specific response.

Of the five tester strains used in the Ames analysis of the transient composite SOF samples, the highest levels of specific activity from all the SOF samples were noted for strains TA100 and TA98. Relative to the specific activities of the SOF derived from use of baseline fuel, the specific activities of the SOF from use of the 5 percent lubricating oil blend were about the same. The specific activities of the SOF derived from use of the EDS and SRC-II blends were notably greater than from the baseline fuel. The specific activities from use of the EDS blend were the highest of all the fuels run. Since the brake specific SOF emission for all the fuels except the soybean oil were similar, the EDS blend also produced the greatest brake specific response. The SOF from use of the soybean oil had the lowest levels of specific activities of any of the fuels tested. The brake specific SOF emission with soybean oil was relatively high at 0.57 g SOF/kW-hr, but the brake specific mutagenic response was low, relative to the levels obtained from the other fuels.

Testing of the SOF derived from the use of the soybean oil indicated high levels of BaP compared to the levels obtained from the use of the other test fuels. Based on BaP content, it would be expected that the brake specific Ames response would have been much greater. Not including the BaP content of the soybean oil-derived SOF, the SOF from use of the EDS blend has the highest BaP content, followed by the SOF derived from the SRC-II blend. Similarly, the SOF from use of the EDS blend had the highest brake specific Ames response, followed by the SOF from use of the SRC-II blend.

TABLE 23. SUMMARY OF AMES RESPONSE TO TRANSIENT COMPOSITE SOF FROM THE MACK EM6-300 ON BASELINE AND ALTERNATE FUELS[a]

Fuel	Total Part. Rate g/kW-hr	Soluble Organic Fract. g/kW-hr	Metab. Activ. Status	Strain TA98 Specific Activity[d] Test 1	Strain TA98 Specific Activity[d] Test 2	Strain TA98 Brake Specific Response[c]	Strain TA100 Specific Activity[b] Test 1	Strain TA100 Specific Activity[b] Test 2	Strain TA100 Brake Specific Response[c]	Strain TA1535 Specific Activity[b] Test 1	Strain TA1535 Specific Activity[b] Test 2	Strain TA1535 Brake Specific Response[c]	Strain TA1537 Specific Activity[b] Test 1	Strain TA1537 Specific Activity[b] Test 2	Strain TA1537 Brake Specific Response[c]	Strain TA1538 Specific Activity[b] Test 1	Strain TA1538 Specific Activity[b] Test 2	Strain TA1538 Brake Specific Response[c]
Baseline	0.79	0.13	Yes	0.36	0.57	0.060	0.96	0.97	0.13	d	d	d	0.097	d	0.013	0.26	0.44	0.046
			No	0.50	0.50	0.065	2.7[e]	1.9[e]	0.29	d	d	d	0.073	d	0.009	0.14	0.25	0.025
25 % EDS	0.70	0.14	Yes	0.58	0.96	0.11	1.1	1.0	0.15	0.063[f]	d	0.009	0.16	d	0.022	0.49[f]	0.62	0.078
			No	0.79	0.73[e]	0.11	3.1[e]	3.1[e]	0.44	0.012	d	0.002	0.25	d	0.035	0.49[e]	d	0.069
25% SRC II	0.67	0.15	Yes	0.49	0.64	0.084	1.0	0.78	0.13	0.023	0.051	0.006	0.14	0.15	0.022	0.48	0.54	0.077
			No	0.68[e]	0.64	0.098	3.0[e]	2.1[e]	0.38	-0.002[f]	-0.017	-0.010	0.20	0.089[f]	0.021	0.47	0.40	0.065
5% Lube Oil	0.83	0.13	Yes	0.38	0.45	0.054	1.0	0.72	0.11	d	d	d	0.069[f]	0.099	0.011	0.22	0.25	0.031
			No	0.56	0.52	0.070	3.0[e]	1.6[e]	0.30	d	d	d	0.063	0.069[f]	0.009	0.24[f]	0.25	0.032
100 % Soybean	0.93	0.57	Yes	0.050	0.069	0.034	0.12	0.13	0.071	-0.013[f]	0.012	0.0003	0.026	0.026	0.015	0.031	0.48	0.023
			No	0.026[f]	0.023	0.014	0.079	0.070	0.042	0.001	0.035	0.010	0.007	0.009	0.005	0.017	0.012	0.008

[a] SOF was submitted in the form of a transient composite sample--samples were run in replicate with about a two-week time span between runs
[b] Specific activity results from statistical analysis--given as "linear slope" revertants/plate per microgram of SOF dose
[c] Brake specific response has units of: millions of revertants/plate per kilowatt hour
[d] not tested
[e] 3 parameter model did not converge
[f] 4 parameter model did not converge

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APPENDIX A

TEST RESULTS WITH BASELINE FUEL
(PHILLIPS D-2, EM-509-F)

TABLE A-1. FULL LOAD PERFORMANCE DATA FROM THE MACK EM6-300 WITH (EM-509-F) BASELINE PHILLIPS 2-DF

Engine Speed	rpm	2100	1900	1700	1500	1260	1000
Torque	ft-lb (N·m)	771 (1045)	855 (1159)	937 (1271)	1005 (1363)	1087 (1474)	1005 (1363)
Power	hp (kW)	308 (230)	309 (231)	303 (226)	287 (214)	261 (195)	191 (142)
Fuel Rate	lb/hr	116.5	111.7	105.6	99.2	91.1	74.7
Fuel Temp.[a]	°F	99	100	100	101	101	102
Fuel Press.[b]	psig	21.6	20.8	19.7	18.5	18.2	16.8
Inlet Air Rate	lb/min	53.8	50.0	44.7	37.6	30.3	20.2
Inlet Air Depress.[c]	in H_2O	36.0	29.0	24.0	17.0	12.0	6.4
Inlet Air Temp.[d]	°F	68	68	68	69	69	71
Turbo Boost Press.	psig	21.6	21.2	19.6	18.0	16.2	11.3
Manifold Inlet Temp.	°F	120	121	121	122	123	120
Exhaust Back. Press.[e]	in Hg	4.8	4.5	3.7	2.9	2.0	1.1
Exhaust Temp.[e]	°F	884	890	930	992	1087	1210
Coolant Water Out	°F	182	182	182	183	184	186

Note: These data taken during run for power curve smoke - mode was held only long enough to record necessary data (approximately 2 minutes)

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[a] Monitored at connection to injection pump
[b] Monitored after fuel filter
[c] Indicated reading using 4 inch tube metering section per 312GS148 of Mack
[d] Monitored upstream of metering section
[e] Indicated reading using 5 inch tube metering section per 312GS148 of Mack

TABLE A-2. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 BASELINE FUEL (PHILLIPS) BAROMETER: 28.96
TEST 01-01 FUEL: EM-509-F PROJECT: 05-5830-014 DATE: 5/12/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.020	3.32	81.	1.071	268.	333.	1.25	290.	24.	61.	92.	1
2	2	INTER / 1260.	30.	3.9	.060	6.95	81.	1.071	308.	381.	1.80	385.	61.	150.	265.	2
3	25	INTER / 1260.	376.	49.6	.197	7.71	81.	1.045	252.	177.	5.30	995.	58.	79.	759.	3
4	50	INTER / 1260.	753.	99.3	.351	9.17	81.	1.022	252.	278.	8.31	1620.	69.	142.	1382.	4
5	75	INTER / 1260.	1128.	148.9	.522	11.90	81.	1.012	150.	999.	9.66	1515.	52.	649.	1625.	5
6	100	INTER / 1260.	1504.	198.5	.699	14.54	81.	1.006	62.	1920.	10.45	1455.	27.	1534.	1908.	6
7		IDLE / 650.	0.	.0	.020	3.19	81.	1.065	236.	314.	1.30	310.	21.	55.	95.	7
8	100	RATED / 2100.	1050.	230.9	.881	26.05	81.	1.031	144.	161.	7.18	665.	113.	239.	1663.	8
9	75	RATED / 2100.	788.	173.3	.682	22.65	81.	1.037	190.	108.	6.32	595.	130.	141.	1315.	9
10	50	RATED / 2100.	525.	115.4	.485	18.83	81.	1.045	226.	123.	5.53	465.	124.	130.	840.	10
11	25	RATED / 2100.	263.	57.9	.308	15.60	81.	1.052	256.	177.	4.31	335.	113.	152.	495.	11
12	2	RATED / 2100.	20.	4.5	.142	11.80	81.	1.061	338.	243.	2.46	225.	117.	167.	268.	12
13		IDLE / 650.	0.	.0	.020	3.24	81.	1.066	272.	323.	1.17	255.	26.	63.	86.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CO	NOX	GRAMS/KW-HR HC	CO	NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	20.77	51.55	78.45	************		******	.0060	.0691	.087	.985	.0062	3.8	.992	*****	.067	1
2	16.81	41.34	73.03	15.49	38.09	67.29	.0088	.0691	.127	.980	.0088	.4	.997	.924	.080	2
3	4.96	6.72	64.39	1.18	1.60	15.32	.0258	.0691	.373	.951	.0249	-3.5	.998	.238	.080	3
4	3.25	6.74	65.52	.69	1.43	13.91	.0388	.0691	.560	.928	.0385	-.8	1.001	.212	.080	4
5	1.67	20.73	51.93	.35	4.36	10.91	.0443	.0691	.641	.917	.0447	.8	1.009	.208	.080	5
6	.64	36.58	45.49	.14	7.73	9.61	.0486	.0691	.703	.911	.0485	-.2	1.019	.207	.080	6
7	17.69	47.00	80.66	************		******	.0062	.0691	.090	.984	.0064	2.9	.994	*****	.067	7
8	2.13	4.53	31.49	.49	1.04	7.21	.0342	.0691	.495	.936	.0333	-2.6	1.084	.211	.080	8
9	3.17	3.45	32.15	.75	.81	7.59	.0305	.0691	.440	.943	.0294	-3.3	1.062	.222	.080	9
10	4.28	4.48	28.89	1.08	1.13	7.27	.0260	.0691	.376	.949	.0259	-.5	1.040	.242	.080	10
11	6.13	8.25	26.80	1.96	2.63	8.55	.0200	.0691	.289	.959	.0204	2.1	1.022	.312	.080	11
12	13.77	19.57	31.38	26.24	37.29	59.80	.0122	.0691	.176	.975	.0119	-2.5	1.014	1.880	.080	12
13	22.44	53.27	73.15	************		******	.0061	.0691	.089	.986	.0058	-4.8	.994	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- =	.854	GRAM/KW-HR	(.637	GRAM/BHP-HR)
BSCO ------- =	3.266	GRAM/KW-HR	(2.436	GRAM/BHP-HR (
BSNOX ------ =	9.933	GRAM/KW-HR	(7.410	GRAM/BHP-HR)
BSHC + BSNOX =	10.787	GRAM/KW-HR	(8.047	GRAM/BHP-HR)
CORR. BSFC - =	.234	KG/KW-HR	(.384	LBS/BHP-HR)

TABLE A-3. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 BASELINE FUEL (PHILLIPS) BAROMETER: 28.90
TEST 01-02 FUEL: EM-509-F PROJECT: 05-5830-014 DATE: 5/12/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.020	3.26	81.	1.066	254.	314.	1.25	295.	23.	57.	94.	1
2	2	INTER / 1260.	30.	3.9	.060	6.87	81.	1.072	280.	332.	1.90	425.	53.	125.	279.	2
3	25	INTER / 1260.	376.	49.6	.197	7.68	81.	1.043	240.	177.	5.23	1005.	56.	80.	776.	3
4	50	INTER / 1260.	753.	99.3	.348	9.18	81.	1.022	234.	243.	8.21	1635.	64.	125.	1398.	4
5	75	INTER / 1260.	1128.	148.9	.522	11.67	81.	1.012	136.	1034.	9.66	1545.	47.	671.	1656.	5
6	100	INTER / 1260.	1504.	198.5	.695	14.51	81.	1.007	60.	1953.	10.45	1470.	26.	1552.	1919.	6
7		IDLE / 650.	0.	.0	.020	3.14	81.	1.061	232.	296.	1.25	310.	21.	54.	99.	7
8	100	RATED / 2100.	1044.	229.7	.878	25.65	81.	1.031	144.	145.	7.09	690.	114.	218.	1743.	8
9	75	RATED / 2100.	784.	172.4	.663	22.40	81.	1.040	196.	108.	6.32	615.	130.	137.	1326.	9
10	50	RATED / 2100.	522.	114.8	.485	18.92	81.	1.048	228.	123.	5.45	470.	127.	132.	865.	10
11	25	RATED / 2100.	262.	57.6	.305	15.48	81.	1.057	260.	169.	4.31	340.	114.	144.	499.	11
12	2	RATED / 2100.	20.	4.5	.140	11.89	81.	1.072	336.	226.	2.40	230.	118.	157.	279.	12
13		IDLE / 650.	0.	.0	.020	3.23	81.	1.077	252.	296.	1.25	295.	23.	54.	95.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	19.73	48.73	79.66	************		******	.0061	.0691	.088	.985	.0062	1.7	.996	*****	.067	1
2	14.58	34.33	76.87	13.43	31.63	70.83	.0089	.0691	.129	.979	.0093	4.2	.999	.922	.080	2
3	4.78	6.81	65.79	1.14	1.62	15.65	.0259	.0691	.375	.952	.0246	-5.2	1.001	.238	.080	3
4	3.05	5.97	67.00	.64	1.25	14.07	.0383	.0691	.554	.928	.0380	-.8	1.005	.209	.080	4
5	1.52	21.45	52.91	.32	4.51	11.12	.0452	.0691	.654	.917	.0447	-1.1	1.012	.208	.080	5
6	.62	37.19	45.99	.13	7.82	9.67	.0485	.0691	.701	.910	.0485	.2	1.023	.205	.080	6
7	18.07	46.08	83.55	************		******	.0063	.0691	.092	.985	.0062	-2.5	.997	*****	.067	7
8	2.16	4.13	33.08	.50	.95	7.59	.0346	.0691	.501	.937	.0329	-5.0	1.087	.211	.080	8
9	3.27	3.45	33.34	.75	.80	7.69	.0299	.0691	.433	.943	.0294	-1.6	1.062	.217	.080	9
10	4.37	4.55	29.72	1.11	1.15	7.53	.0259	.0691	.375	.950	.0255	-1.6	1.042	.243	.080	10
11	6.23	7.87	27.31	1.98	2.50	8.67	.0199	.0691	.288	.959	.0204	2.3	1.024	.310	.080	11
12	14.02	18.66	33.20	26.30	34.99	62.26	.0119	.0691	.172	.975	.0116	-2.5	1.013	1.851	.080	12
13	19.60	46.01	80.60	************		******	.0062	.0691	.089	.985	.0062	.5	.994	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- =	.839	GRAM/KW-HR	(.626	GRAM/BHP-HR)
BSCO ------- =	3.224	GRAM/KW-HR	(2.405	GRAM/BHP-HR (
BSNOX ------ =	10.174	GRAM/KW-HR	(7.590	GRAM/BHP-HR)
BSHC + BSNOX =	11.013	GRAM/KW-HR	(8.216	GRAM/BHP-HR)
CORR. BSFC - =	.232	KG/KW-HR	(.382	LBS/BHP-HR)

TABLE A-4. TRANSIENT POWER MAP FROM THE MACK EM6-300 ON BASELINE FUEL EM-509-F (PHILLIPS 2-DF)

Speed rpm	Torque N•m (ft lbs)	Speed rpm	Torque N•m (ft lbs)
100	542 (400)	1300	1508 (1112)
200	542 (400)	1400	1477 (1089)
300	542 (400)	1500	1413 (1042)
400	542 (400)	1600	1361 (1003)
500	542 (400)	1700	1322 (975)
600	579 (427)	1800	1250 (922)
700	651 (480)	1900	1184 (873)
800	858 (633)	2000	1124 (829)
900	1229 (906)	2100	1045 (771)
1000	1397 (1030)	2200	461 (340)
1100	1530 (1128)	2300	0 (0)
1200	1573 (1160)		

Idle Speed 650 rpm
Max Torque 1573 N•m (1160 ft-lb) @ 1200 rpm
Max Power 235.5 kW (315.7 hp) @ 2000 rpm

Transient Command Cycle Power, kW-hr (hp-hr)

NYNF	LANF	LAF	NYNF	TOTAL
2.09	3.10	8.98	2.07	16.24
(2.80)	(4.15)	(12.04)	(2.78)	(21.77)

TABLE A-5. REGULATED EMISSIONS SUMMARY FROM TRANSIENT FTP OPERATION OF THE MACK EM6-300 ENGINE WITH (EM-509-F) BASELINE PHILLIPS 2-DF

Cycle Type	Transient Emissions, g/kW-hr (g/hp-hr)					Cycle BSFC kg/kW-hr (lb/hp-hr)	Cycle Work kW-hr (hp-hr)
			NO_x				
	HC	CO	Cont.	Bag	Part.		
Cold Start	0.90 (0.67)	4.76 (3.55)	10.46 (7.80)	Void	0.88 (0.66)	0.273 (0.448)	16.79 (22.52)
Hot Start	0.82 (0.61)	4.21 (3.14)	10.35 (7.72)	Void	0.77 (0.57)	0.265 (0.436)	16.13 (21.63)
Transient Composite	0.83 (0.62)	4.29 (3.20)	10.37 (7.73)	Void	0.79 (0.58)	0.266 (0.428)	16.22 (21.76)
Cold Start	0.86 (0.64)	5.36 (4.00)	10.16 (7.58)	8.65 (6.45)	0.89 (0.66)	0.266 (0.437)	16.03 (21.50)
Hot Start	1.03 (0.77)	4.73 (3.53)	9.94 (7.42)	8.63 (6.43)	0.83 (0.62)	0.260 (0.427)	16.07 (21.55)
Transient Composite	1.01 (0.75)	4.82 (3.60)	9.97 (7.44)	8.63 (6.43)	0.84 (0.63)	0.261 (0.428)	16.06 (21.54)
Cold Start	0.85 (0.63)	4.74 (3.53)	10.33 (7.71)	8.53 (6.36)	0.78 (0.59)	0.266 (0.438)	16.16 (21.67)
Hot Start	0.85 (0.63)	4.14 (3.09)	10.17 (7.58)	8.72 (6.50)	0.75 (0.56)	0.263 (0.432)	16.26 (21.81)
Transient Composite	0.85 (0.63)	4.23 (3.15)	10.19 (7.60)	8.69 (6.48)	0.75 (0.56)	0.263 (0.433)	16.25 (21.79)

TABLE A-6. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-3 RUN1
DATE 5/10/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 739.39 MM HG(29.11 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-45. PCT , CVS-66. PCT
ABSOLUTE HUMIDITY 8.9 GM/KG(62.0 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.8	304.9	297.9
TOT. BLOWER RATE SCMM (SCFM)	61.79 (2181.8)	61.80 (2182.0)	61.79 (2181.8)	61.78 (2181.6)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.03 (1.18)	.03 (1.18)	.03 (1.18)	.03 (1.18)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	305.0 (10770.)	308.9 (10909.)	314.2 (11093.)	306.9 (10837.)
HC SAMPLE METER/RANGE/PPM	6.3/13/ 25.	7.2/13/ 29.	11.6/13/ 46.	5.8/13/ 23.
HC BCKGRD METER/RANGE/PPM	9.7/ 1/ 10.	9.8/ 1/ 10.	11.0/ 1/ 11.	10.7/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	80.7/13/ 80.	61.4/13/ 59.	37.7/13/ 35.	63.9/13/ 62.
CO BCKGRD METER/RANGE/PPM	1.3/13/ 1.	1.1/13/ 1.	1.4/13/ 1.	2.0/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	26.8/ 3/ .44	35.1/ 3/ .59	72.0/ 3/ 1.30	24.7/ 3/ .40
CO2 BCKGRD METER/RANGE/PCT	3.4/ 3/ .05	3.4/ 3/ .05	3.7/ 3/ .06	3.8/ 3/ .06
NOX SAMPLE METER/RANGE/PPM	4.5/14/ 45.	5.6/14/ 56.	14.6/14/ 146.	4.9/14/ 49.
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ 0.	.2/ 2/ 0.	.3/ 2/ 0.	.3/ 2/ 0.
DILUTION FACTOR	29.82	22.48	10.21	32.63
HC CONCENTRATION PPM	16.	19.	36.	13.
CO CONCENTRATION PPM	76.	56.	32.	58.
CO2 CONCENTRATION PCT	.39	.54	1.25	.35
NOX CONCENTRATION PPM	45.0	55.5	146.1	49.0
HC MASS GRAMS	2.80	3.43	6.59	2.27
CO MASS GRAMS	27.15	20.18	11.79	20.76
CO2 MASS GRAMS	2170.6	3041.8	7211.6	1943.5
NOX MASS GRAMS	26.28	32.81	87.80	28.77
FUEL KG (LB)	.700 (1.54)	.971 (2.14)	2.283 (5.03)	.625 (1.38)
KW HR (HP HR)	2.20 (2.95)	3.09 (4.14)	9.28 (12.45)	2.22 (2.98)
BSHC G/KW HR (G/HP HR)	1.27 (.95)	1.11 (.83)	.71 (.53)	1.02 (.76)
BSCO G/KW HR (G/HP HR)	12.34 (9.20)	6.54 (4.87)	1.27 (.95)	9.34 (6.97)
BSCO2 G/KW HR (G/HP HR)	986.72 (735.80)	985.28 (734.73)	776.78 (579.24)	874.60 (652.19)
BSNOX G/KW HR (G/HP HR)	11.94 (8.91)	10.63 (7.92)	9.46 (7.05)	12.95 (9.65)
BSFC KG/KW HR (LB/HP HR)	.318 (.523)	.315 (.517)	.246 (.404)	.281 (.462)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.79 (22.52)
BSHC G/KW HR (G/HP HR)	.90 (.67)
BSCO G/KW HR (G/HP HR)	4.76 (3.55)
BSCO2 G/KW HR (G/HP HR)	856. (638.)
BSNOX G/KW HR (G/HP HR)	10.46 (7.80)
BSFC KG/KW HR (LB/HP HR)	.273 (.448)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	14.81
	G/KWHR(G/HPHR)	.88 (.66)
	G/KG FUEL (G/LB FUEL)	3.23 (1.47)
	FILTER EFF.	97.2

TABLE A-7. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5483-008

ENGINE NO.D3
ENGINE MODEL 0 MACK
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-4 RUN1
DATE 5/10/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 739.39 MM HG(29.11 IN HG)
DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)

RELATIVE HUMIDITY , ENGINE-48. PCT , CVS-66. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(61.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	305.0	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.78 (2181.5)	61.80 (2182.0)	61.80 (2182.1)	61.81 (2182.3)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.63)	.05 (1.63)	.05 (1.63)	.05 (1.63)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	305.0 (10770.)	309.1 (10915.)	314.4 (11101.)	307.0 (10840.)
HC SAMPLE METER/RANGE/PPM	21.4/11/ 21.	26.2/11/ 26.	45.4/11/ 45.	21.6/11/ 22.
HC BCKGRD METER/RANGE/PPM	10.9/ 1/ 11.	10.7/ 1/ 11.	10.5/ 1/ 11.	10.3/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	64.2/13/ 62.	51.5/13/ 49.	37.0/13/ 34.	60.2/13/ 58.
CO BCKGRD METER/RANGE/PPM	1.5/13/ 1.	1.8/13/ 2.	2.2/13/ 2.	2.5/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	23.5/ 3/ .38	31.8/ 3/ .53	69.2/ 3/ 1.25	24.0/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05	3.0/ 3/ .05	3.2/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	4.4/14/ 44.	5.0/14/ 50.	13.8/14/ 138.	4.9/14/ 49.
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ 0.	.2/ 2/ 0.	.3/ 2/ 0.	.2/ 2/ 0.
DILUTION FACTOR	34.38	25.04	10.67	33.67
HC CONCENTRATION PPM	11.	16.	36.	12.
CO CONCENTRATION PPM	59.	46.	31.	54.
CO2 CONCENTRATION PCT	.34	.48	1.20	.34
NOX CONCENTRATION PPM	44.2	50.2	137.6	49.1
HC MASS GRAMS	1.90	2.83	6.50	2.06
CO MASS GRAMS	20.90	16.42	11.34	19.26
CO2 MASS GRAMS	1873.6	2737.8	6927.1	1909.2
NOX MASS GRAMS	25.77	29.69	82.72	28.84
FUEL KG (LB)	.602 (1.33)	.873 (1.92)	2.193 (4.84)	.613 (1.35)
KW HR (HP HR)	2.17 (2.91)	2.99 (4.01)	8.87 (11.90)	2.10 (2.81)
BSHC G/KW HR (G/HP HR)	.88 (.65)	.95 (.71)	.73 (.55)	.98 (.73)
BSCO G/KW HR (G/HP HR)	9.63 (7.18)	5.49 (4.10)	1.28 (.95)	9.19 (6.85)
BSCO2 G/KW HR (G/HP HR)	863.41 (643.84)	915.57 (682.74)	780.62 (582.11)	911.13 (679.43)
BSNOX G/KW HR (G/HP HR)	11.87 (8.85)	9.93 (7.40)	9.32 (6.95)	13.76 (10.26)
BSFC KG/KW HR (LB/HP HR)	.278 (.456)	.292 (.480)	.247 (.406)	.292 (.481)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.13 (21.63)
BSHC G/KW HR (G/HP HR)	.82 (.61)
BSCO G/KW HR (G/HP HR)	4.21 (3.14)
BSCO2 G/KW HR (G/HP HR)	834. (622.)
BSNOX G/KW HR (G/HP HR)	10.35 (7.72)
BSFC KG/KW HR (LB/HP HR)	.265 (.436)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	12.36
	G/KWHR(G/HPHR)	.77 (.57)
	G/KG FUEL (G/LB FUEL)	2.89 (1.31)
	FILTER EFF.	97.4

TABLE A-8. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-3 RUN1
DATE 5/11/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 738.12 MM HG(29.06 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-42. PCT , CVS-68. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(61.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	305.1	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.88 (2149.7)	60.88 (2149.5)	60.89 (2150.0)	60.90 (2150.2)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.62)	.05 (1.62)	.05 (1.62)	.05 (1.62)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	300.6 (10613.)	304.5 (10752.)	309.9 (10941.)	302.5 (10680.)
HC SAMPLE METER/RANGE/PPM	27.3/11/ 27.	27.2/11/ 27.	44.0/11/ 44.	20.9/11/ 21.
HC BCKGRD METER/RANGE/PPM	10.5/ 1/ 11.	10.8/ 1/ 11.	11.2/ 1/ 11.	10.9/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	86.5/13/ 87.	66.2/13/ 64.	45.0/13/ 42.	68.4/13/ 66.
CO BCKGRD METER/RANGE/PPM	2.1/13/ 2.	2.3/13/ 2.	2.2/13/ 2.	2.2/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	26.7/ 3/ .44	32.5/ 3/ .54	68.2/ 3/ 1.23	23.7/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.4/ 3/ .05	3.7/ 3/ .06	3.6/ 3/ .06	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	15.9/13/ 48.	17.0/13/ 51.	44.9/13/ 135.	16.3/13/ 49.
NOX BCKGRD METER/RANGE/PPM	.9/ 2/ 1.	1.1/ 2/ 1.	.4/ 3/ 1.	.9/ 2/ 1.
DILUTION FACTOR	29.88	24.39	10.84	34.05
HC CONCENTRATION PPM	17.	17.	34.	10.
CO CONCENTRATION PPM	82.	60.	38.	63.
CO2 CONCENTRATION PCT	.39	.49	1.18	.33
NOX CONCENTRATION PPM	46.7	49.9	133.7	48.0
HC MASS GRAMS	2.97	2.96	6.04	1.80
CO MASS GRAMS	28.73	21.28	13.88	22.04
CO2 MASS GRAMS	2129.4	2709.6	6679.8	1852.3
NOX MASS GRAMS	26.85	29.08	79.23	27.77
FUEL KG (LB)	.688 (1.52)	.867 (1.91)	2.116 (4.67)	.596 (1.31)
KW HR (HP HR)	2.11 (2.83)	2.95 (3.95)	8.87 (11.89)	2.11 (2.83)
BSHC G/KW HR (G/HP HR)	1.41 (1.05)	1.01 (.75)	.68 (.51)	.85 (.64)
BSCO G/KW HR (G/HP HR)	13.61 (10.15)	7.23 (5.39)	1.57 (1.17)	10.44 (7.79)
BSCO2 G/KW HR (G/HP HR)	1009.04 (752.44)	919.91 (685.98)	753.39 (561.80)	877.71 (654.51)
BSNOX G/KW HR (G/HP HR)	12.72 (9.49)	9.87 (7.36)	8.94 (6.66)	13.16 (9.81)
BSFC KG/KW HR (LB/HP HR)	.326 (.536)	.294 (.484)	.239 (.392)	.282 (.464)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.03 (21.50)
BSHC G/KW HR (G/HP HR)	.86 (.64)
BSCO G/KW HR (G/HP HR)	5.36 (4.00)
BSCO2 G/KW HR (G/HP HR)	834. (622.)
BSNOX G/KW HR (G/HP HR)	10.16 (7.58)
BSFC KG/KW HR (LB/HP HR)	.266 (.437)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	14.28
	G/KWHR (G/HPHR)	.89 (.66)
	G/KG FUEL (G/LB FUEL)	3.35 (1.52)
	FILTER EFF.	97.9

Table A-8 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-3 RUN1
DATE 5/11/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 738.12 MM HG(29.06 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-42. PCT , CVS-68. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(61.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	305.1	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.88 (2149.7)	60.88 (2149.5)	60.89 (2150.0)	60.90 (2150.2)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.62)	.05 (1.62)	.05 (1.62)	.05 (1.62)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	300.6 (10613.)	304.5 (10752.)	309.9 (10941.)	302.5 (10680.)
HC SAMPLE METER/RANGE/PPM	27.3/11/ 27.	27.2/11/ 27.	44.0/11/ 44.	20.9/11/ 21.
HC BCKGRD METER/RANGE/PPM	10.5/ 1/ 11.	10.8/ 1/ 11.	11.2/ 1/ 11.	10.9/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	86.5/13/ 87.	66.2/13/ 64.	45.0/13/ 42.	68.4/13/ 66.
CO BCKGRD METER/RANGE/PPM	2.1/13/ 2.	2.3/13/ 2.	2.2/13/ 2.	2.2/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	26.7/ 3/ .44	32.5/ 3/ .54	68.2/ 3/ 1.23	23.7/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.4/ 3/ .05	3.7/ 3/ .06	3.6/ 3/ .06	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	41.6/ 2/ 42.	44.8/ 2/ 45.	37.2/ 3/ 112.	42.9/ 2/ 43.
NOX BCKGRD METER/RANGE/PPM	.9/ 2/ 1.	1.1/ 2/ 1.	.4/ 3/ 1.	.9/ 2/ 1.
DILUTION FACTOR	29.88	24.39	10.84	34.05
HC CONCENTRATION PPM	17.	17.	34.	10.
CO CONCENTRATION PPM	82.	60.	38.	63.
CO2 CONCENTRATION PCT	.39	.49	1.18	.33
NOX CONCENTRATION PPM	40.7	43.7	110.5	42.0
HC MASS GRAMS	2.97	2.96	6.04	1.80
CO MASS GRAMS	28.73	21.28	13.88	22.04
CO2 MASS GRAMS	2129.4	2709.6	6679.8	1852.3
NOX MASS GRAMS	23.41	25.47	65.48	24.31
FUEL KG (LB)	.688 (1.52)	.867 (1.91)	2.116 (4.67)	.596 (1.31)
KW HR (HP HR)	2.11 (2.83)	2.95 (3.95)	8.87 (11.89)	2.11 (2.83)
BSHC G/KW HR (G/HP HR)	1.41 (1.05)	1.01 (.75)	.68 (.51)	.85 (.64)
BSCO G/KW HR (G/HP HR)	13.61 (10.15)	7.23 (5.39)	1.57 (1.17)	10.44 (7.79)
BSCO2 G/KW HR (G/HP HR)	1009.04 (752.44)	919.91 (685.98)	753.39 (561.80)	877.71 (654.51)
BSNOX G/KW HR (G/HP HR)	11.09 (8.27)	8.65 (6.45)	7.39 (5.51)	11.52 (8.59)
BSFC KG/KW HR (LB/HP HR)	.326 (.536)	.294 (.484)	.239 (.392)	.282 (.464)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.03 (21.50)
BSHC G/KW HR (G/HP HR)	.86 (.64)
BSCO G/KW HR (G/HP HR)	5.36 (4.00)
BSCO2 G/KW HR (G/HP HR)	834. (622.)
BSNOX G/KW HR (G/HP HR)	8.65 (6.45) Bag
BSFC KG/KW HR (LB/HP HR)	.266 (.437)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	14.28
	G/KWHR(G/HPHR)	.89 (.66)
	G/KG FUEL (G/LB FUEL)	3.35 (1.52)
	FILTER EFF.	97.9

TABLE A-9. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) 1-6
CVS NO. 11

TEST NO.D3-4 RUN1
DATE 5/11/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 738.12 MM HG(29.06 IN HG)
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)

RELATIVE HUMIDITY , ENGINE-39. PCT , CVS-68. PCT
ABSOLUTE HUMIDITY 8.8 GM/KG(61.4 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	305.0	297.9
TOT. BLOWER RATE SCMM (SCFM)	60.87 (2149.4)	60.89 (2149.9)	60.91 (2150.7)	60.88 (2149.8)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.61)	.05 (1.61)	.05 (1.61)	.05 (1.61)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	300.5 (10611.)	304.6 (10754.)	309.9 (10941.)	302.5 (10682.)
HC SAMPLE METER/RANGE/PPM	23.0/11/ 23.	31.9/11/ 32.	49.5/11/ 50.	27.0/11/ 27.
HC BCKGRD METER/RANGE/PPM	10.7/ 1/ 11.	10.1/ 1/ 10.	9.7/ 1/ 10.	9.2/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	69.1/13/ 67.	57.5/13/ 55.	41.3/13/ 38.	67.7/13/ 66.
CO BCKGRD METER/RANGE/PPM	1.1/13/ 1.	1.2/13/ 1.	1.1/13/ 1.	1.2/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	23.0/ 3/ .37	31.4/ 3/ .52	69.0/ 3/ 1.24	23.1/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.2/ 3/ .05	3.3/ 3/ .05	2.9/ 3/ .04	3.0/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	14.2/13/ 43.	17.5/13/ 53.	44.7/13/ 134.	16.0/13/ 48.
NOX BCKGRD METER/RANGE/PPM	.9/ 2/ 1.	1.2/ 2/ 1.	.5/ 3/ 2.	1.2/ 2/ 1.
DILUTION FACTOR	35.10	25.32	10.70	34.92
HC CONCENTRATION PPM	13.	22.	41.	18.
CO CONCENTRATION PPM	64.	52.	36.	63.
CO2 CONCENTRATION PCT	.33	.47	1.20	.33
NOX CONCENTRATION PPM	41.7	51.4	132.8	47.0
HC MASS GRAMS	2.18	3.90	7.28	3.15
CO MASS GRAMS	22.49	18.47	12.93	22.09
CO2 MASS GRAMS	1790.1	2632.5	6828.1	1828.2
NOX MASS GRAMS	23.99	29.95	78.68	27.18
FUEL KG (LB)	.577 (1.27)	.842 (1.86)	2.164 (4.77)	.590 (1.30)
KW HR (HP HR)	2.21 (2.96)	2.97 (3.98)	8.80 (11.80)	2.10 (2.81)
BSHC G/KW HR (G/HP HR)	.99 (.74)	1.31 (.98)	.83 (.62)	1.51 (1.12)
BSCO G/KW HR (G/HP HR)	10.19 (7.60)	6.22 (4.64)	1.47 (1.10)	10.54 (7.86)
BSCO2 G/KW HR (G/HP HR)	811.00 (604.77)	887.00 (661.44)	775.99 (578.66)	872.48 (650.61)
BSNOX G/KW HR (G/HP HR)	10.87 (8.10)	10.09 (7.53)	8.94 (6.67)	12.97 (9.67)
BSFC KG/KW HR (LB/HP HR)	.261 (.430)	.284 (.466)	.246 (.404)	.281 (.463)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.07 (21.55)
BSHC G/KW HR (G/HP HR)	1.03 (.77)
BSCO G/KW HR (G/HP HR)	4.73 (3.53)
BSCO2 G/KW HR (G/HP HR)	814. (607.)
BSNOX G/KW HR (G/HP HR)	9.94 (7.42)
BSFC KG/KW HR (LB/HP HR)	.260 (.427)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	13.31
	G/KWHR(G/HPHR)	.83 (.62)
	G/KG FUEL (G/LB FUEL)	3.19 (1.45)
	FILTER EFF.	97.9

TABLE A-9 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-4 RUN1
DATE 5/11/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 738.12 MM HG(29.06 IN HG)
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)

RELATIVE HUMIDITY , ENGINE-39. PCT , CVS-68. PCT
ABSOLUTE HUMIDITY 8.8 GM/KG(61.4 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	305.0	297.9
TOT. BLOWER RATE SCMM (SCFM)	60.87 (2149.4)	60.89 (2149.9)	60.91 (2150.7)	60.88 (2149.8)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.61)	.05 (1.61)	.05 (1.61)	.05 (1.61)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	300.5 (10611.)	304.6 (10754.)	309.9 (10941.)	302.5 (10682.)
HC SAMPLE METER/RANGE/PPM	23.0/11/ 23.	31.9/11/ 32.	49.5/11/ 50.	27.0/11/ 27.
HC BCKGRD METER/RANGE/PPM	10.7/ 1/ 11.	10.1/ 1/ 10.	9.7/ 1/ 10.	9.2/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	69.1/13/ 67.	57.5/13/ 55.	41.3/13/ 38.	67.7/13/ 66.
CO BCKGRD METER/RANGE/PPM	1.1/13/ 1.	1.2/13/ 1.	1.1/13/ 1.	1.2/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	23.0/ 3/ .37	31.4/ 3/ .52	69.0/ 3/ 1.24	23.1/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.2/ 3/ .05	3.3/ 3/ .05	2.9/ 3/ .04	3.0/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	38.0/ 2/ 38.	45.6/ 2/ 46.	38.6/ 3/ 116.	42.0/ 2/ 42.
NOX BCKGRD METER/RANGE/PPM	.9/ 2/ 1.	1.2/ 2/ 1.	.5/ 3/ 2.	1.2/ 2/ 1.
DILUTION FACTOR	35.10	25.32	10.70	34.92
HC CONCENTRATION PPM	13.	22.	41.	18.
CO CONCENTRATION PPM	64.	52.	36.	63.
CO2 CONCENTRATION PCT	.33	.47	1.20	.33
NOX CONCENTRATION PPM	37.1	44.4	114.4	40.8
HC MASS GRAMS	2.18	3.90	7.28	3.15
CO MASS GRAMS	22.49	18.47	12.93	22.09
CO2 MASS GRAMS	1790.1	2632.5	6828.1	1828.2
NOX MASS GRAMS	21.34	25.89	67.81	23.62
FUEL KG (LB)	.577 (1.27)	.842 (1.86)	2.164 (4.77)	.590 (1.30)
KW HR (HP HR)	2.21 (2.96)	2.97 (3.98)	8.80 (11.80)	2.10 (2.81)
BSHC G/KW HR (G/HP HR)	.99 (.74)	1.31 (.98)	.83 (.62)	1.51 (1.12)
BSCO G/KW HR (G/HP HR)	10.19 (7.60)	6.22 (4.64)	1.47 (1.10)	10.54 (7.86)
BSCO2 G/KW HR (G/HP HR)	811.00 (604.77)	887.00 (661.44)	775.99 (578.66)	872.48 (650.61)
BSNOX G/KW HR (G/HP HR)	9.67 (7.21)	8.72 (6.50)	7.71 (5.75)	11.27 (8.41)
BSFC KG/KW HR (LB/HP HR)	.261 (.430)	.284 (.466)	.246 (.404)	.281 (.463)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.07 (21.55)
BSHC G/KW HR (G/HP HR)	1.03 (.77)
BSCO G/KW HR (G/HP HR)	4.73 (3.53)
BSCO2 G/KW HR (G/HP HR)	814. (607.)
BSNOX G/KW HR (G/HP HR)	8.63 (6.43) Bag
BSFC KG/KW HR (LB/HP HR)	.260 (.427)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	13.31
	G/KWHR(G/HPHR)	.83 (.62)
	G/KG FUEL (G/LB FUEL)	3.19 (1.45)
	FILTER EFF.	97.9

TABLE A-10. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-5 RUN1
DATE 5/12/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 736.35 MM HG(28.99 IN HG)
DRY BULB TEMP. 21.1 DEG C(70.0 DEG F)

RELATIVE HUMIDITY , ENGINE-55. PCT , CVS-74. PCT
ABSOLUTE HUMIDITY 8.9 GM/KG(62.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	305.0	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.72 (2143.9)	60.73 (2144.4)	60.73 (2144.5)	60.73 (2144.4)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.60)	.05 (1.60)	.05 (1.60)	.05 (1.60)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.7 (10581.)	303.8 (10726.)	309.0 (10909.)	301.6 (10651.)
HC SAMPLE METER/RANGE/PPM	24.1/11/ 24.	27.2/11/ 27.	45.2/11/ 45.	21.0/11/ 21.
HC BCKGRD METER/RANGE/PPM	10.1/ 1/ 10.	10.0/ 1/ 10.	10.8/ 1/ 11.	10.6/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	79.2/13/ 78.	61.4/13/ 59.	37.3/13/ 35.	60.4/13/ 58.
CO BCKGRD METER/RANGE/PPM	1.4/13/ 1.	1.3/13/ 1.	1.3/13/ 1.	1.2/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	25.2/ 3/ .41	33.6/ 3/ .56	68.5/ 3/ 1.23	23.7/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.2/ 3/ .05	3.0/ 3/ .05	2.9/ 3/ .04	3.0/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	15.0/13/ 45.	18.1/13/ 54.	45.7/13/ 137.	17.4/13/ 52.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.	.6/ 2/ 1.	.2/ 3/ 1.	.7/ 2/ 1.
DILUTION FACTOR	31.82	23.56	10.79	34.12
HC CONCENTRATION PPM	14.	18.	35.	11.
CO CONCENTRATION PPM	75.	56.	32.	55.
CO2 CONCENTRATION PCT	.36	.52	1.19	.34
NOX CONCENTRATION PPM	44.4	53.6	136.6	51.5
HC MASS GRAMS	2.47	3.09	6.30	1.87
CO MASS GRAMS	26.03	19.74	11.48	19.34
CO2 MASS GRAMS	1994.9	2871.8	6750.8	1880.3
NOX MASS GRAMS	25.44	31.13	80.69	29.73
FUEL KG (LB)	.644 (1.42)	.917 (2.02)	2.138 (4.71)	.604 (1.33)
KW HR (HP HR)	2.16 (2.89)	2.98 (4.00)	8.91 (11.95)	2.11 (2.83)
BSHC G/KW HR (G/HP HR)	1.15 (.86)	1.04 (.77)	.71 (.53)	.89 (.66)
BSCO G/KW HR (G/HP HR)	12.08 (9.01)	6.62 (4.94)	1.29 (.96)	9.16 (6.83)
BSCO2 G/KW HR (G/HP HR)	925.68 (690.28)	962.77 (717.94)	757.57 (564.92)	891.02 (664.43)
BSNOX G/KW HR (G/HP HR)	11.80 (8.80)	10.44 (7.78)	9.05 (6.75)	14.09 (10.51)
BSFC KG/KW HR (LB/HP HR)	.299 (.491)	.307 (.505)	.240 (.394)	.286 (.470)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.16 (21.67)
BSHC G/KW HR (G/HP HR)	.85 (.63)
BSCO G/KW HR (G/HP HR)	4.74 (3.53)
BSCO2 G/KW HR (G/HP HR)	835. (623.)
BSNOX G/KW HR (G/HP HR)	10.33 (7.71)
BSFC KG/KW HR (LB/HP HR)	.266 (.438)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	12.68
	G/KWHR(G/HPHR)	.78 (.59)
	G/KG FUEL (G/LB FUEL)	2.95 (1.34)
	FILTER EFF.	97.7

TABLE A-10 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-5 RUN1
DATE 5/12/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 736.35 MM HG(28.99 IN HG)
DRY BULB TEMP. 21.1 DEG C(70.0 DEG F)

RELATIVE HUMIDITY , ENGINE-55. PCT , CVS-74. PCT
ABSOLUTE HUMIDITY 8.9 GM/KG(62.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	305.0	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.72 (2143.9)	60.73 (2144.4)	60.73 (2144.5)	60.73 (2144.4)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.60)	.05 (1.60)	.05 (1.60)	.05 (1.60)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.7 (10581.)	303.8 (10726.)	309.0 (10909.)	301.6 (10651.)
HC SAMPLE METER/RANGE/PPM	24.1/11/ 24.	27.2/11/ 27.	45.2/11/ 45.	21.0/11/ 21.
HC BCKGRD METER/RANGE/PPM	10.1/ 1/ 10.	10.0/ 1/ 10.	10.8/ 1/ 11.	10.6/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	79.2/13/ 78.	61.4/13/ 59.	37.3/13/ 35.	60.4/13/ 58.
CO BCKGRD METER/RANGE/PPM	1.4/13/ 1.	1.3/13/ 1.	1.3/13/ 1.	1.2/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	25.2/ 3/ .41	33.6/ 3/ .56	68.5/ 3/ 1.23	23.7/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.2/ 3/ .05	3.0/ 3/ .05	2.9/ 3/ .04	3.0/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	39.1/ 2/ 39.	47.4/ 2/ 47.	35.8/ 3/ 107.	44.7/ 2/ 45.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.	.6/ 2/ 1.	.2/ 3/ 1.	.7/ 2/ 1.
DILUTION FACTOR	31.82	23.56	10.79	34.12
HC CONCENTRATION PPM	14.	18.	35.	11.
CO CONCENTRATION PPM	75.	56.	32.	55.
CO2 CONCENTRATION PCT	.36	.52	1.19	.34
NOX CONCENTRATION PPM	38.5	46.8	106.9	44.0
HC MASS GRAMS	2.47	3.09	6.30	1.87
CO MASS GRAMS	26.03	19.74	11.48	19.34
CO2 MASS GRAMS	1994.9	2871.8	6750.8	1880.3
NOX MASS GRAMS	22.07	27.20	63.14	25.39
FUEL KG (LB)	.644 (1.42)	.917 (2.02)	2.138 (4.71)	.604 (1.33)
KW HR (HP HR)	2.16 (2.89)	2.98 (4.00)	8.91 (11.95)	2.11 (2.83)
BSHC G/KW HR (G/HP HR)	1.15 (.86)	1.04 (.77)	.71 (.53)	.89 (.66)
BSCO G/KW HR (G/HP HR)	12.08 (9.01)	6.62 (4.94)	1.29 (.96)	9.16 (6.83)
BSCO2 G/KW HR (G/HP HR)	925.68 (690.28)	962.77 (717.94)	757.57 (564.92)	891.02 (664.43)
BSNOX G/KW HR (G/HP HR)	10.24 (7.64)	9.12 (6.80)	7.09 (5.28)	12.03 (8.97)
BSFC KG/KW HR (LB/HP HR)	.299 (.491)	.307 (.505)	.240 (.394)	.286 (.470)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.16 (21.67)
BSHC G/KW HR (G/HP HR)	.85 (.63)
BSCO G/KW HR (G/HP HR)	4.74 (3.53)
BSCO2 G/KW HR (G/HP HR)	835. (623.)
BSNOX G/KW HR (G/HP HR)	8.53 (6.36) Bag
BSFC KG/KW HR (LB/HP HR)	.266 (.438)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	12.68
	G/KWHR(G/HPHR)	.78 (.59)
	G/KG FUEL (G/LB FUEL)	2.95 (1.34)
	FILTER EFF.	97.7

TABLE A-11. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-6 RUN1
DATE 5/12/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 736.35 MM HG(28.99 IN HG)
DRY BULB TEMP. 21.1 DEG C(70.0 DEG F)

RELATIVE HUMIDITY , ENGINE-55. PCT , CVS-75. PCT
ABSOLUTE HUMIDITY 8.9 GM/KG(62.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.91 (2150.6)	60.91 (2150.7)	60.91 (2150.9)	60.90 (2150.3)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.60)	.05 (1.60)	.05 (1.60)	.05 (1.60)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	300.6 (10614.)	304.7 (10758.)	309.8 (10938.)	302.5 (10681.)
HC SAMPLE METER/RANGE/PPM	20.1/11/ 20.	25.4/11/ 25.	49.8/11/ 50.	21.9/11/ 22.
HC BCKGRD METER/RANGE/PPM	10.7/ 1/ 11.	10.3/ 1/ 10.	10.2/ 1/ 10.	10.2/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	62.3/13/ 60.	52.7/13/ 50.	36.6/13/ 34.	60.2/13/ 58.
CO BCKGRD METER/RANGE/PPM	1.3/13/ 1.	1.1/13/ 1.	1.1/13/ 1.	1.3/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	23.0/ 3/ .37	31.7/ 3/ .53	70.2/ 3/ 1.27	23.8/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	2.8/ 3/ .04	2.7/ 3/ .04	2.8/ 3/ .04	2.7/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	15.8/13/ 47.	18.0/13/ 54.	44.8/13/ 134.	16.4/13/ 49.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.	.6/ 2/ 1.	.2/ 3/ 1.	.7/ 2/ 1.
DILUTION FACTOR	35.19	25.12	10.50	33.96
HC CONCENTRATION PPM	10.	16.	41.	12.
CO CONCENTRATION PPM	57.	47.	31.	55.
CO2 CONCENTRATION PCT	.33	.49	1.23	.35
NOX CONCENTRATION PPM	46.9	53.4	133.8	48.5
HC MASS GRAMS	1.69	2.73	7.25	2.09
CO MASS GRAMS	19.92	16.77	11.32	19.28
CO2 MASS GRAMS	1823.5	2713.3	6973.1	1920.0
NOX MASS GRAMS	26.94	31.14	79.25	28.05
FUEL KG (LB)	.586 (1.29)	.865 (1.91)	2.209 (4.87)	.616 (1.36)
KW HR (HP HR)	2.21 (2.97)	3.02 (4.05)	8.90 (11.94)	2.13 (2.85)
BSHC G/KW HR (G/HP HR)	.76 (.57)	.91 (.67)	.81 (.61)	.99 (.73)
BSCO G/KW HR (G/HP HR)	8.99 (6.71)	5.55 (4.14)	1.27 (.95)	9.07 (6.77)
BSCO2 G/KW HR (G/HP HR)	823.36 (613.98)	898.41 (669.94)	783.17 (584.01)	903.45 (673.70)
BSNOX G/KW HR (G/HP HR)	12.16 (9.07)	10.31 (7.69)	8.90 (6.64)	13.20 (9.84)
BSFC KG/KW HR (LB/HP HR)	.264 (.435)	.287 (.471)	.248 (.408)	.290 (.477)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.26 (21.81)
BSHC G/KW HR (G/HP HR)	.85 (.63)
BSCO G/KW HR (G/HP HR)	4.14 (3.09)
BSCO2 G/KW HR (G/HP HR)	826. (616.)
BSNOX G/KW HR (G/HP HR)	10.17 (7.58)
BSFC KG/KW HR (LB/HP HR)	.263 (.432)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	12.13
	G/KWHR(G/HPHR)	.75 (.56)
	G/KG FUEL (G/LB FUEL)	2.84 (1.29)
	FILTER EFF.	97.5

TABLE A-11 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-6 RUN1
DATE 5/12/82
TIME
DYNO NO. 4

DIESEL EM-509-F
BAG CART NO. 1

BAROMETER 736.35 MM HG(28.99 IN HG)
DRY BULB TEMP. 21.1 DEG C(70.0 DEG F)

RELATIVE HUMIDITY , ENGINE-55. PCT , CVS-75. PCT
ABSOLUTE HUMIDITY 8.9 GM/KG(62.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.91 (2150.6)	60.91 (2150.7)	60.91 (2150.9)	60.90 (2150.3)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.60)	.05 (1.60)	.05 (1.60)	.05 (1.60)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	300.6 (10614.)	304.7 (10758.)	309.8 (10938.)	302.5 (10681.)
HC SAMPLE METER/RANGE/PPM	20.1/11/ 20.	25.4/11/ 25.	49.8/11/ 50.	21.9/11/ 22.
HC BCKGRD METER/RANGE/PPM	10.7/ 1/ 11.	10.3/ 1/ 10.	10.2/ 1/ 10.	10.2/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	62.3/13/ 60.	52.7/13/ 50.	36.6/13/ 34.	60.2/13/ 58.
CO BCKGRD METER/RANGE/PPM	1.3/13/ 1.	1.1/13/ 1.	1.1/13/ 1.	1.3/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	23.0/ 3/ .37	31.7/ 3/ .53	70.2/ 3/ 1.27	23.8/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	2.8/ 3/ .04	2.7/ 3/ .04	2.8/ 3/ .04	2.7/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	41.2/ 2/ 41.	47.6/ 2/ 48.	37.4/ 3/ 112.	43.8/ 2/ 44.
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ 1.	.6/ 2/ 1.	.2/ 3/ 1.	.7/ 2/ 1.
DILUTION FACTOR	35.19	25.12	10.50	33.96
HC CONCENTRATION PPM	10.	16.	41.	12.
CO CONCENTRATION PPM	57.	47.	31.	55.
CO2 CONCENTRATION PCT	.33	.49	1.23	.35
NOX CONCENTRATION PPM	40.6	47.0	111.7	43.1
HC MASS GRAMS	1.69	2.73	7.25	2.09
CO MASS GRAMS	19.92	16.77	11.32	19.28
CO2 MASS GRAMS	1823.5	2713.3	6973.1	1920.0
NOX MASS GRAMS	23.35	27.40	66.15	24.94
FUEL KG (LB)	.586 (1.29)	.865 (1.91)	2.209 (4.87)	.616 (1.36)
KW HR (HP HR)	2.21 (2.97)	3.02 (4.05)	8.90 (11.94)	2.13 (2.85)
BSHC G/KW HR (G/HP HR)	.76 (.57)	.91 (.67)	.81 (.61)	.99 (.73)
BSCO G/KW HR (G/HP HR)	8.99 (6.71)	5.55 (4.14)	1.27 (.95)	9.07 (6.77)
BSCO2 G/KW HR (G/HP HR)	823.36 (613.98)	898.41 (669.94)	783.17 (584.01)	903.45 (673.70)
BSNOX G/KW HR (G/HP HR)	10.54 (7.86)	9.07 (6.77)	7.43 (5.54)	11.74 (8.75)
BSFC KG/KW HR (LB/HP HR)	.264 (.435)	.287 (.471)	.248 (.408)	.290 (.477)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.26 (21.81)
BSHC G/KW HR (G/HP HR)	.85 (.63)
BSCO G/KW HR (G/HP HR)	4.14 (3.09)
BSCO2 G/KW HR (G/HP HR)	826. (616.)
BSNOX G/KW HR (G/HP HR)	8.72 (6.50) Bag
BSFC KG/KW HR (LB/HP HR)	.263 (.432)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	12.13
	G/KWHR (G/HPHR)	.75 (.56)
	G/KG FUEL (G/LB FUEL)	2.84 (1.29)
	FILTER EFF.	97.5

TABLE A-12. TRANSIENT CYCLE STATISTICS AND MODAL EMISSION RATE SUMMARY

TRANSIENT CYCLE STATISTICS

TEST D3-1	Cold Cycle Speed	Cold Cycle Torque	Cold Cycle Power	Hot Cycle Speed	Hot Cycle Torque	Hot Cycle Power
Standard Error	41.5	4.3	4.7	38.9	4.4	4.7
Slope	1.0008	0.9993	1.0353	0.9970	0.9587	0.997
Corr. Coef.	0.995	0.971	0.979	0.996	0.969	0.979
Intercept	12.6	7.4	0.8	17.2	4.3	-0.6
Points Used	1179	974	974	1179	990	990
Ref. Work (Dev. %)	21.77	(3.42)		21.77	(-0.69)	

TEST D3-3	Cold Cycle Speed	Cold Cycle Torque	Cold Cycle Power	Hot Cycle Speed	Hot Cycle Torque	Hot Cycle Power
Standard Error	41.0	4.2	4.6	40.4	4.4	4.9
Slope	0.9980	0.9689	1.0007	0.9965	0.9541	0.9931
Corr. Coef.	0.995	0.971	0.979	0.995	0.968	0.976
Intercept	15.6	1.6	-0.7	17.4	5.9	-0.6
Points Used	1179	980	980	1179	985	985
Ref. Work (Dev.%)	21.77	(-1.21)		21.77	(-1.02)	

TEST D3-5	Cold Cycle Speed	Cold Cycle Torque	Cold Cycle Power	Hot Cycle Speed	Hot Cycle Torque	Hot Cycle Power
Standard Error	45.0	4.2	4.6	42.7	4.1	4.7
Slope	1.0056	0.9610	1.0042	1.0037	0.9519	1.0002
Corr. Coef.	0.994	0.971	0.979	0.995	0.972	0.978
Intercept	8.9	4.3	-0.5	14.5	8.4	-0.1
Points Used	1179	983	983	1179	991	991
Ref. Work (Dev. %)	21.77	(-0.43)		21.77	(-0.18)	

Note:
Units are as given in Federal Register Section 86.134-84

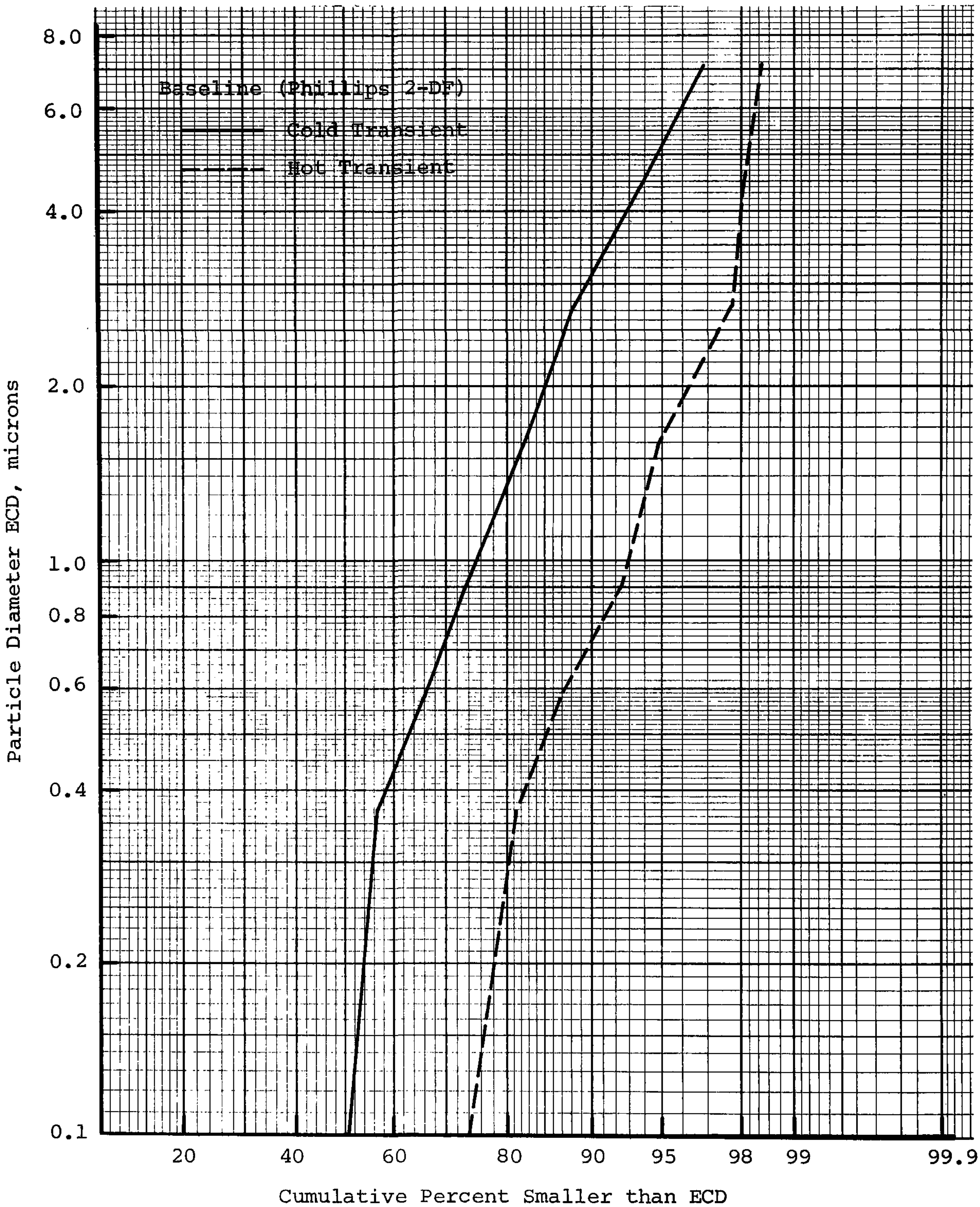

Figure A-1. Particle size distribution from transient operation of the Mack EM6-300 with baseline fuel (Phillip 2-DF)

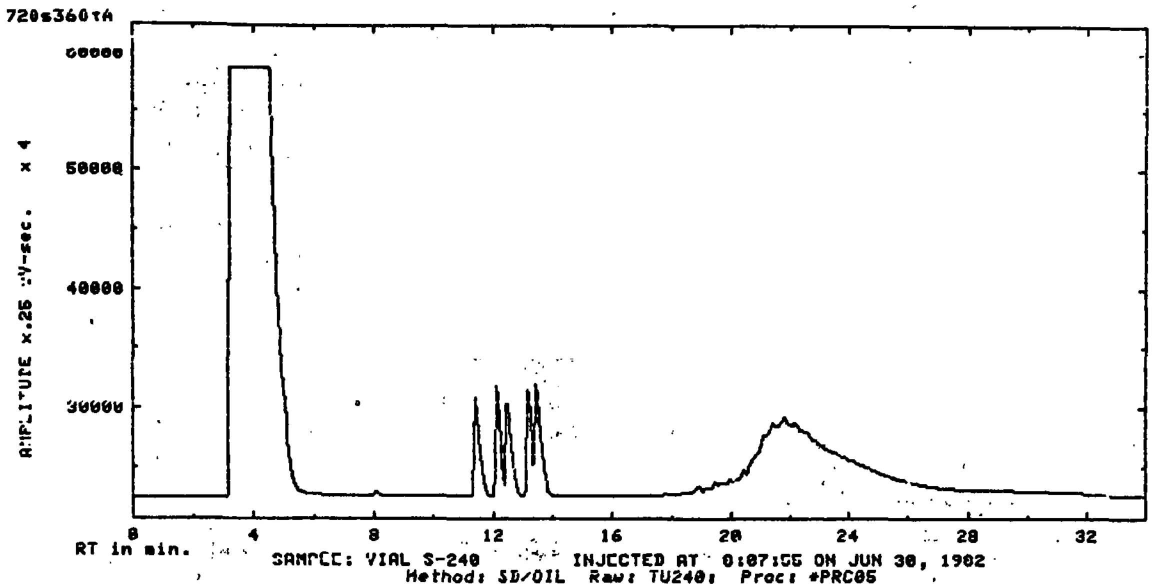

Figure A-2. Boiling Point Distribution of SOF derived from cold-start transient operation with baseline fuel

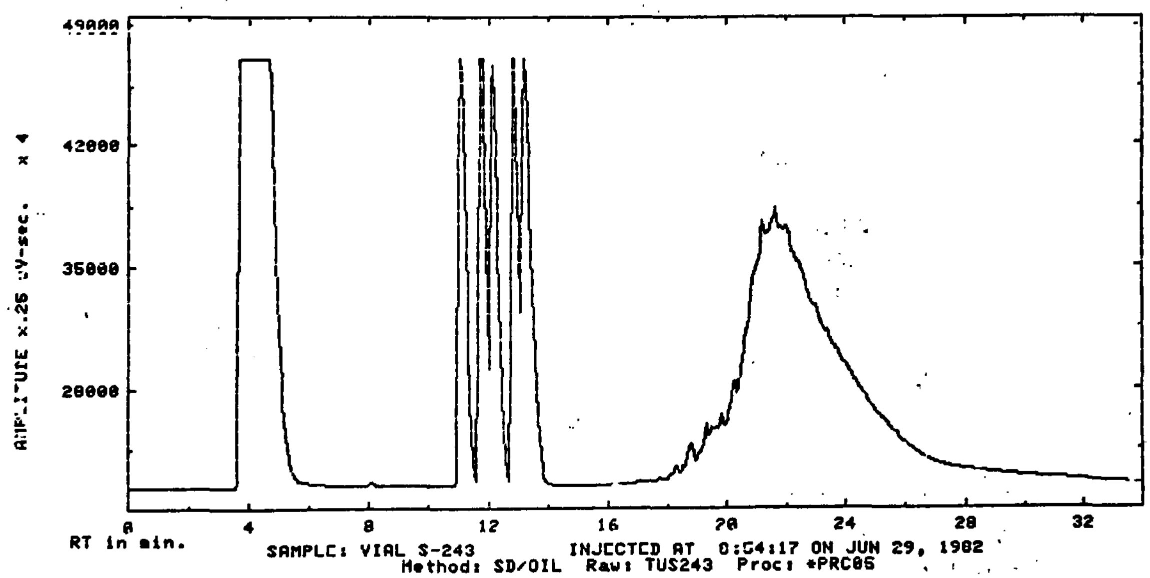

Figure A-3. Boiling Point Distribution of SOF derived from hot-start transient operation with baseline fuel

APPENDIX B

TEST RESULTS WITH 25 PERCENT EDS (EM-515-F)

TABLE B-1. FULL LOAD PERFORMANCE DATA FROM THE MACK EM6-300 WITH (EM-515-F) 25 PERCENT EDS BLEND

Engine Speed	rpm	2100	1900	1700	1500	1260	1000
Torque	ft-lb	800	885	977	1050	1138	1087
	(N•m)	(1085)	(1200)	(1325)	(1424)	(1543)	(1474)
Power	hp	320	320	316	300	273	207
	(kW)	(239)	(329)	(236)	(224)	(204)	(154)
Fuel Rate	lb/hr	121.1	115.7	109.4	102.1	94.6	79.5
Fuel Temp.[a]	°F	89	92	93	94	94	94
Fuel Press.[b]	psig	21.0	20.0	19.2	19.4	18.0	16.0
Inlet Air Rate	lb/min	58.0	53.5	48.2	40.2	32.8	22.5
Inlet Air Depress.[c]	in H_2O	36.0	32.0	25.0	18.2	12.7	7.5
Inlet Air Temp.[d]	°F	67	67	68	68	69	70
Turbo Boost Press.	psig	23.2	22.8	21.4	19.3	17.6	13.0
Manifold Inlet Temp.	°F	120	121	121	121	119	108
Exhaust Back. Press.[e]	in Hg	2.7	2.8	2.5	1.8	1.3	0.7
Exhaust Temp.[e]	°F	823	850	893	960	1052	1143
Coolant Water Out	°F	180	183	183	185	186	187

Note: These data taken during run for power curve smoke - mode was held only long enough to record necessary data (approximately 2 minutes)

[a] Monitored at connection to injection pump
[b] Monitored after fuel filter
[c] Indicated reading using 4 inch tube metering section per 312GS148 of Mack
[d] Monitored upstream of metering section
[e] Indicated reading using 5 inch tube metering section per 312GS148 of Mack

TABLE B-2. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 EDS BLEND BAROMETER: 29.20
TEST-02-01 FUEL: EM-515-F PROJECT: 05-5830-014 DATE: 05/18/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.020	3.33	68.	1.033	328.	465.	1.21	260.	30.	87.	82.	1
2	2	INTER / 1260.	30.	3.9	.060	6.95	68.	1.034	344.	520.	1.85	405.	66.	199.	261.	2
3	25	INTER / 1260.	377.	49.8	.191	7.69	68.	1.016	240.	185.	5.38	1215.	53.	80.	870.	3
4	50	INTER / 1260.	753.	99.3	.344	9.34	68.	.999	226.	234.	8.31	1860.	60.	118.	1529.	4
5	75	INTER / 1260.	1130.	149.1	.517	11.91	68.	.991	152.	778.	9.66	1740.	52.	505.	1826.	5
6	100	INTER / 1260.	1533.	202.2	.716	15.00	68.	.985	76.	1447.	10.45	1665.	34.	1197.	2213.	6
7		IDLE / 650.	0.	.0	.020	3.33	68.	1.028	300.	432.	1.21	275.	28.	81.	87.	7
8	100	RATED / 2100.	1071.	235.6	.909	25.76	68.	1.004	136.	130.	7.27	780.	108.	198.	1949.	8
9	75	RATED / 2100.	785.	172.7	.661	22.80	68.	1.012	184.	101.	6.24	665.	123.	131.	1419.	9
10	50	RATED / 2100.	524.	115.1	.492	19.18	68.	1.017	218.	123.	5.53	535.	121.	133.	962.	10
11	25	RATED / 2100.	262.	57.6	.300	14.94	68.	1.022	244.	193.	4.24	410.	107.	166.	587.	11
12	2	RATED / 2100.	20.	4.5	.147	12.45	68.	1.034	332.	314.	2.56	295.	115.	216.	342.	12
13		IDLE / 650.	0.	.0	.020	3.36	68.	1.028	324.	432.	1.21	270.	30.	81.	85.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	GRAMS/KW-HR HC	GRAMS/KW-HR CO	GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	25.79	73.62	69.36	******	******	******	.0060	.0698	.085	.986	.0061	2.0	.980	*****	.067	1
2	18.11	54.82	72.03	16.68	50.51	66.37	.0088	.0698	.126	.981	.0091	3.6	.986	.934	.080	2
3	4.64	6.97	75.81	1.07	1.61	17.48	.0251	.0698	.360	.953	.0251	-.0	.987	.234	.080	3
4	2.90	5.72	74.11	.60	1.19	15.40	.0372	.0698	.533	.931	.0382	2.9	.991	.210	.080	4
5	1.69	16.29	58.88	.35	3.39	12.25	.0438	.0698	.628	.921	.0444	1.3	.997	.209	.080	5
6	.78	27.87	51.54	.17	5.92	10.94	.0482	.0698	.691	.915	.0481	-.2	1.008	.211	.080	6
7	23.70	68.72	73.38	******	******	******	.0060	.0698	.085	.986	.0060	1.4	.984	*****	.067	7
8	1.98	3.64	35.75	.46	.84	8.27	.0356	.0698	.511	.939	.0335	-5.9	1.070	.216	.080	8
9	3.10	3.29	35.77	.71	.76	8.22	.0293	.0698	.420	.947	.0289	-1.3	1.047	.220	.080	9
10	4.11	4.51	32.58	1.05	1.16	8.35	.0259	.0698	.371	.952	.0258	-.6	1.026	.250	.080	10
11	5.92	9.20	32.60	1.85	2.88	10.20	.0203	.0698	.291	.962	.0199	-1.7	1.008	.310	.080	11
12	12.97	24.42	38.72	25.63	48.27	76.53	.0120	.0698	.171	.975	.0123	2.9	1.000	1.977	.080	12
13	25.55	68.59	71.92	******	******	******	.0059	.0698	.085	.986	.0061	2.6	.984	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- =	.838	GRAM/KW-HR	(.625	GRAM/BHP-HR)
BSCO ------- =	2.891	GRAM/KW-HR	(2.157	GRAM/BHP-HR (
BSNOX ------ =	11.168	GRAM/KW-HR	(8.331	GRAM/BHP-HR)
BSHC + BSNOX =	12.006	GRAM/KW-HR	(8.956	GRAM/BHP-HR)
CORR. BSFC - =	.236	KG/KW-HR	(.387	LBS/BHP-HR)

TABLE B-3. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 EDS BLEND BAROMETER: 29.18
TEST-02-02 FUEL:EM-515-F PROJECT: 05-5830-104 DATE: 5/19/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.020	3.36	89.	1.104	300.	432.	1.30	280.	26.	76.	88.	1
2	2	INTER / 1260.	30.	3.9	.060	6.92	89.	1.103	360.	532.	1.75	380.	72.	214.	275.	2
3	25	INTER / 1260.	377.	49.8	.187	7.78	89.	1.071	246.	193.	5.45	1185.	53.	81.	866.	3
4	50	INTER / 1260.	753.	99.3	.336	9.27	89.	1.044	232.	217.	8.11	1845.	62.	110.	1588.	4
5	75	INTER / 1260.	1130.	149.1	.518	11.64	89.	1.026	156.	822.	9.66	1725.	54.	534.	1878.	5
6	100	INTER / 1260.	1546.	204.0	.710	14.89	89.	1.020	76.	1521.	10.45	1650.	33.	1247.	2250.	6
7		IDLE / 650.	0.	.0	.020	3.30	89.	1.093	300.	432.	1.21	280.	28.	81.	94.	7
8	100	RATED / 2100.	1074.	236.2	.905	26.33	89.	1.051	148.	138.	7.36	770.	116.	207.	1981.	8
9	75	RATED / 2100.	785.	172.7	.672	22.64	89.	1.061	188.	101.	6.41	675.	125.	129.	1494.	9
10	50	RATED / 2100.	524.	115.1	.467	18.76	89.	1.072	212.	123.	5.45	515.	114.	128.	940.	10
11	25	RATED / 2100.	262.	57.6	.295	14.88	89.	1.081	246.	201.	4.24	395.	106.	169.	587.	11
12	2	RATED / 2100.	20.	4.5	.135	11.98	89.	1.102	344.	333.	2.40	275.	115.	222.	330.	12
13		IDLE / 650.	0.	.0	.020	3.33	89.	1.104	334.	443.	1.21	250.	31.	83.	84.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	22.19	64.22	74.97	************		******	.0059	.0698	.085	.984	.0065	9.2	.985	*****	.067	1
2	19.95	59.04	75.89	18.38	54.41	69.93	.0088	.0698	.127	.981	.0087	-2.2	.989	.931	.080	2
3	4.70	7.17	76.98	1.06	1.62	17.40	.0244	.0698	.350	.952	.0254	4.2	.990	.228	.080	3
4	3.05	5.43	78.68	.62	1.10	15.99	.0367	.0698	.526	.932	.0373	1.7	.993	.205	.080	4
5	1.74	17.20	60.44	.36	3.58	12.59	.0451	.0698	.646	.920	.0444	-1.4	1.000	.208	.080	5
6	.78	29.27	52.83	.16	6.11	11.03	.0483	.0698	.692	.914	.0481	-.2	1.011	.206	.080	6
7	23.72	68.72	79.42	************		******	.0060	.0698	.086	.985	.0060	.4	.988	*****	.067	7
8	2.14	3.81	36.49	.49	.88	8.39	.0348	.0698	.499	.938	.0339	-2.5	1.073	.214	.080	8
9	3.09	3.20	37.04	.72	.75	8.65	.0301	.0698	.431	.945	.0297	-1.2	1.022	.228	.080	9
10	4.06	4.58	33.55	.99	1.11	8.17	.0252	.0698	.361	.952	.0254	.7	1.028	.237	.080	10
11	5.97	9.58	33.21	1.83	2.94	10.20	.0201	.0698	.287	.961	.0199	-.6	1.012	.304	.080	11
12	14.28	27.55	40.91	25.77	49.70	73.82	.0114	.0698	.163	.976	.0116	1.7	1.003	1.800	.080	12
13	26.32	70.22	71.40	************		******	.0060	.0698	.086	.985	.0061	1.7	.985	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- = .843 GRAM/KW-HR (.629 GRAM/BHP-HR)
BSCO ------- = 2.968 GRAM/KW-HR (2.214 GRAM/BHP-HR (
BSNOX ------ = 11.363 GRAM/KW-HR (8.477 GRAM/BHP-HR)
BSHC + BSNOX = 12.206 GRAM/KW-HR (9.106 GRAM/BHP-HR)
CORR. BSFC - = .233 KG/KW-HR (.383 LBS/BHP-HR)

TABLE B-4. REGULATED EMISSIONS SUMMARY FROM TRANSIENT FTP OPERATION OF THE MACK EM6-300 ENGINE WITH (EM-515-F) 25 PERCENT EDS BLEND

Cycle Type	Transient Emissions, g/kW-hr (g/hp-hr)					Cycle BSFC kg/kW-hr (lb/hp-hr)	Cycle Work kW-hr (hp-hr)
			NO_x				
	HC	CO	Cont.	Bag	Part.		
Cold Start	1.00 (0.75)	5.31 (3.96)	11.44 (8.53)	9.94 (7.41)	0.77 (0.58)	0.272 (0.447)	16.04 (21.51)
Hot Start	0.86 (0.64)	4.31 (3.22)	11.12 (8.29)	9.83 (7.33)	0.71 (0.53)	0.265 (0.436)	16.12 (21.62)
Transient Composite	0.88 (0.66)	4.45 (3.33)	11.17 (8.32)	9.85 (7.34)	0.72 (0.54)	0.266 (0.438)	16.11 (21.60)
Cold Start	0.98 (0.73)	4.98 (3.71)	11.19 (8.35)	9.75 (7.27)	0.72 (0.53)	0.268 (0.441)	15.93 (21.36)
Hot Start	0.88 (0.65)	4.12 (3.07)	11.08 (8.26)	9.66 (7.21)	0.68 (0.51)	0.256 (0.420)	15.91 (21.34)
Transient Composite	0.89 (0.66)	4.24 (3.16)	11.10 (8.27)	9.67 (7.22)	0.69 (0.51)	0.258 (0.423)	15.91 (21.34)

TABLE B-5. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-14 RUN2
DATE 5/19/82
TIME
DYNO NO. 4

DIESEL EM-515-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-43. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 8.4 GM/KG(59.1 GRAINS/LB)

NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.14 (2158.9)	61.15 (2159.1)	61.16 (2159.6)	61.16 (2159.4)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.65)	.05 (1.65)	.05 (1.65)	.05 (1.65)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.8 (10655.)	305.9 (10800.)	311.0 (10983.)	303.8 (10726.)
HC SAMPLE METER/RANGE/PPM	32.1/11/ 32.	28.6/11/ 29.	45.0/11/ 45.	23.5/11/ 24.
HC BCKGRD METER/RANGE/PPM	9.8/ 1/ 10.	10.1/ 1/ 10.	10.1/ 1/ 10.	10.1/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	92.0/13/ 93.	67.0/13/ 65.	37.1/13/ 34.	62.3/13/ 60.
CO BCKGRD METER/RANGE/PPM	1.0/13/ 1.	1.3/13/ 1.	1.1/13/ 1.	1.5/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	26.5/ 3/ .43	33.7/ 3/ .56	68.8/ 3/ 1.24	23.1/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	2.9/ 3/ .04	3.2/ 3/ .05	2.6/ 3/ .04	2.5/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	16.8/13/ 50.	20.1/13/ 60.	50.7/13/ 152.	17.6/13/ 53.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.	.7/ 2/ 1.	.3/ 3/ 1.	1.0/ 2/ 1.
DILUTION FACTOR	30.04	23.46	10.74	35.00
HC CONCENTRATION PPM	23.	19.	36.	14.
CO CONCENTRATION PPM	89.	62.	32.	57.
CO2 CONCENTRATION PCT	.39	.52	1.20	.34
NOX CONCENTRATION PPM	49.7	59.5	151.2	51.7
HC MASS GRAMS	3.93	3.33	6.42	2.41
CO MASS GRAMS	31.39	22.01	11.59	20.15
CO2 MASS GRAMS	2159.7	2885.1	6854.8	1877.4
NOX MASS GRAMS	28.68	34.83	89.94	30.03
FUEL KG (LB)	.694 (1.53)	.915 (2.02)	2.153 (4.75)	.599 (1.32)
KW HR (HP HR)	2.10 (2.81)	2.95 (3.95)	8.93 (11.98)	2.07 (2.77)
BSHC G/KW HR (G/HP HR)	1.88 (1.40)	1.13 (.84)	.72 (.54)	1.16 (.87)
BSCO G/KW HR (G/HP HR)	14.98 (11.17)	7.47 (5.57)	1.30 (.97)	9.76 (7.28)
BSCO2 G/KW HR (G/HP HR)	1030.67 (768.57)	979.48 (730.40)	767.31 (572.18)	908.89 (677.76)
BSNOX G/KW HR (G/HP HR)	13.69 (10.21)	11.82 (8.82)	10.07 (7.51)	14.54 (10.84)
BSFC KG/KW HR (LB/HP HR)	.331 (.544)	.311 (.511)	.241 (.396)	.290 (.477)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.04 (21.51)
BSHC G/KW HR (G/HP HR)	1.00 (.75)
BSCO G/KW HR (G/HP HR)	5.31 (3.96)
BSCO2 G/KW HR (G/HP HR)	859. (640.)
BSNOX G/KW HR (G/HP HR)	11.44 (8.53)
BSFC KG/KW HR (LB/HP HR)	.272 (.447)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	12.42
	G/KWHR(G/HPHR)	.77 (.58)
	G/KG FUEL (G/LB FUEL)	2.85 (1.29)
	FILTER EFF.	97.0

TABLE B-5 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-14 RUN2
DATE 5/19/82
TIME
DYNO NO. 4

DIESEL EM-515-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-43. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 8.4 GM/KG(59.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.14 (2158.9)	61.15 (2159.1)	61.16 (2159.6)	61.16 (2159.4)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.65)	.05 (1.65)	.05 (1.65)	.05 (1.65)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.8 (10655.)	305.9 (10800.)	311.0 (10983.)	303.8 (10726.)
HC SAMPLE METER/RANGE/PPM	32.1/11/ 32.	28.6/11/ 29.	45.0/11/ 45.	23.5/11/ 24.
HC BCKGRD METER/RANGE/PPM	9.8/ 1/ 10.	10.1/ 1/ 10.	10.1/ 1/ 10.	10.1/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	92.0/13/ 93.	67.0/13/ 65.	37.1/13/ 34.	62.3/13/ 60.
CO BCKGRD METER/RANGE/PPM	1.0/13/ 1.	1.3/13/ 1.	1.1/13/ 1.	1.5/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	26.5/ 3/ .43	33.7/ 3/ .56	68.8/ 3/ 1.24	23.1/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	2.9/ 3/ .04	3.2/ 3/ .05	2.6/ 3/ .04	2.5/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	46.9/ 2/ 47.	54.0/ 2/ 54.	42.1/ 3/ 126.	47.4/ 2/ 47.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.	.7/ 2/ 1.	.3/ 3/ 1.	1.0/ 2/ 1.
DILUTION FACTOR	30.04	23.46	10.74	35.00
HC CONCENTRATION PPM	23.	19.	36.	14.
CO CONCENTRATION PPM	89.	62.	32.	57.
CO2 CONCENTRATION PCT	.39	.52	1.20	.34
NOX CONCENTRATION PPM	46.2	53.3	125.5	46.4
HC MASS GRAMS	3.93	3.33	6.42	2.41
CO MASS GRAMS	31.39	22.01	11.59	20.15
CO2 MASS GRAMS	2159.7	2885.1	6854.8	1877.4
NOX MASS GRAMS	26.67	31.19	74.64	26.97
FUEL KG (LB)	.694 (1.53)	.915 (2.02)	2.153 (4.75)	.599 (1.32)
KW HR (HP HR)	2.10 (2.81)	2.95 (3.95)	8.93 (11.98)	2.07 (2.77)
BSHC G/KW HR (G/HP HR)	1.88 (1.40)	1.13 (.84)	.72 (.54)	1.16 (.87)
BSCO G/KW HR (G/HP HR)	14.98 (11.17)	7.47 (5.57)	1.30 (.97)	9.76 (7.28)
BSCO2 G/KW HR (G/HP HR)	1030.67 (768.57)	979.48 (730.40)	767.31 (572.18)	908.89 (677.76)
BSNOX G/KW HR (G/HP HR)	12.73 (9.49)	10.59 (7.90)	8.36 (6.23)	13.06 (9.74)
BSFC KG/KW HR (LB/HP HR)	.331 (.544)	.311 (.511)	.241 (.396)	.290 (.477)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.04 (21.51)
BSHC G/KW HR (G/HP HR)	1.00 (.75)
BSCO G/KW HR (G/HP HR)	5.31 (3.96)
BSCO2 G/KW HR (G/HP HR)	859. (640.) Bag
BSNOX G/KW HR (G/HP HR)	9.94 (7.41)
BSFC KG/KW HR (LB/HP HR)	.272 (.447)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	12.42
G/KWHR(G/HPHR)	.77 (.58)
G/KG FUEL (G/LB FUEL)	2.85 (1.29)
FILTER EFF.	97.0

TABLE B-6. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-15 RUN2
DATE 5/19/82
TIME
DYNO NO. 4

DIESEL EM-515-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-43. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 8.1 GM/KG(56.4 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.8	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.23 (2162.0)	61.25 (2162.9)	61.24 (2162.2)	61.23 (2162.1)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.64)	.05 (1.64)	.05 (1.64)	.05 (1.64)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	302.2 (10670.)	306.3 (10815.)	311.4 (10996.)	304.1 (10739.)
HC SAMPLE METER/RANGE/PPM	23.2/11/ 23.	27.1/11/ 27.	45.7/11/ 46.	24.2/11/ 24.
HC BCKGRD METER/RANGE/PPM	11.7/ 1/ 12.	11.0/ 1/ 11.	10.5/ 1/ 11.	10.7/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	66.6/13/ 64.	57.1/13/ 54.	34.8/13/ 32.	58.9/13/ 56.
CO BCKGRD METER/RANGE/PPM	1.1/13/ 1.	1.7/13/ 2.	1.8/13/ 2.	1.7/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	23.6/ 3/ .38	32.5/ 3/ .54	70.0/ 3/ 1.26	22.5/ 3/ .36
CO2 BCKGRD METER/RANGE/PCT	2.5/ 3/ .04	2.7/ 3/ .04	2.5/ 3/ .04	2.7/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	17.2/13/ 52.	19.9/13/ 60.	49.6/13/ 149.	16.9/13/ 51.
NOX BCKGRD METER/RANGE/PPM	1.6/ 2/ 2.	1.6/ 2/ 2.	.5/ 3/ 2.	2.0/ 2/ 2.
DILUTION FACTOR	34.19	24.43	10.54	36.00
HC CONCENTRATION PPM	12.	17.	36.	14.
CO CONCENTRATION PPM	62.	51.	29.	53.
CO2 CONCENTRATION PCT	.35	.50	1.23	.32
NOX CONCENTRATION PPM	50.1	58.3	147.4	48.8
HC MASS GRAMS	2.07	2.92	6.49	2.42
CO MASS GRAMS	21.73	18.32	10.63	18.89
CO2 MASS GRAMS	1915.5	2808.7	7010.7	1805.3
NOX MASS GRAMS	28.97	34.13	87.79	28.40
FUEL KG (LB)	.611 (1.35)	.889 (1.96)	2.202 (4.85)	.576 (1.27)
KW HR (HP HR)	2.14 (2.87)	2.98 (3.99)	8.93 (11.98)	2.07 (2.78)
BSHC G/KW HR (G/HP HR)	.97 (.72)	.98 (.73)	.73 (.54)	1.17 (.87)
BSCO G/KW HR (G/HP HR)	10.15 (7.57)	6.16 (4.59)	1.19 (.89)	9.11 (6.80)
BSCO2 G/KW HR (G/HP HR)	895.03 (667.43)	943.98 (703.92)	784.76 (585.20)	870.85 (649.40)
BSNOX G/KW HR (G/HP HR)	13.54 (10.09)	11.47 (8.55)	9.83 (7.33)	13.70 (10.22)
BSFC KG/KW HR (LB/HP HR)	.286 (.469)	.299 (.491)	.246 (.405)	.278 (.456)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.12 (21.62)
BSHC G/KW HR (G/HP HR)	.86 (.64)
BSCO G/KW HR (G/HP HR)	4.31 (3.22)
BSCO2 G/KW HR (G/HP HR)	840. (626.)
BSNOX G/KW HR (G/HP HR)	11.12 (8.29)
BSFC KG/KW HR (LB/HP HR)	.265 (.436)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	11.41
	G/KWHR(G/HPHR)	.71 (.53)
	G/KG FUEL (G/LB FUEL)	2.67 (1.21)
	FILTER EFF.	97.7

TABLE B-6.(Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-15 RUN2
DATE 5/19/82
TIME
DYNO NO. 4

DIESEL EM-515-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-43. PCT , CVS-62. PCT
ABSOLUTE HUMIDITY 8.1 GM/KG(56.4 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.8	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.23 (2162.0)	61.25 (2162.9)	61.24 (2162.2)	61.23 (2162.1)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.64)	.05 (1.64)	.05 (1.64)	.05 (1.64)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	302.2 (10670.)	306.3 (10815.)	311.4 (10996.)	304.1 (10739.)
HC SAMPLE METER/RANGE/PPM	23.2/11/ 23.	27.1/11/ 27.	45.7/11/ 46.	24.2/11/ 24.
HC BCKGRD METER/RANGE/PPM	11.7/ 1/ 12.	11.0/ 1/ 11.	10.5/ 1/ 11.	10.7/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	66.6/13/ 64.	57.1/13/ 54.	34.8/13/ 32.	58.9/13/ 56.
CO BCKGRD METER/RANGE/PPM	1.1/13/ 1.	1.7/13/ 2.	1.8/13/ 2.	1.7/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	23.6/ 3/ .38	32.5/ 3/ .54	70.0/ 3/ 1.26	22.5/ 3/ .36
CO2 BCKGRD METER/RANGE/PCT	2.5/ 3/ .04	2.7/ 3/ .04	2.5/ 3/ .04	2.7/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	47.3/ 2/ 47.	54.6/ 2/ 55.	42.9/ 3/ 129.	45.2/ 2/ 45.
NOX BCKGRD METER/RANGE/PPM	1.6/ 2/ 2.	1.6/ 2/ 2.	.5/ 3/ 2.	2.0/ 2/ 2.
DILUTION FACTOR	34.19	24.43	10.54	36.00
HC CONCENTRATION PPM	12.	17.	36.	14.
CO CONCENTRATION PPM	62.	51.	29.	53.
CO2 CONCENTRATION PCT	.35	.50	1.23	.32
NOX CONCENTRATION PPM	45.7	53.1	127.3	43.3
HC MASS GRAMS	2.07	2.92	6.49	2.42
CO MASS GRAMS	21.73	18.32	10.63	18.89
CO2 MASS GRAMS	1915.5	2808.7	7010.7	1805.3
NOX MASS GRAMS	26.44	31.08	75.84	25.16
FUEL KG (LB)	.611 (1.35)	.889 (1.96)	2.202 (4.85)	.576 (1.27)
KW HR (HP HR)	2.14 (2.87)	2.98 (3.99)	8.93 (11.98)	2.07 (2.78)
BSHC G/KW HR (G/HP HR)	.97 (.72)	.98 (.73)	.73 (.54)	1.17 (.87)
BSCO G/KW HR (G/HP HR)	10.15 (7.57)	6.16 (4.59)	1.19 (.89)	9.11 (6.80)
BSCO2 G/KW HR (G/HP HR)	895.03 (667.43)	943.98 (703.92)	784.76 (585.20)	870.85 (649.40)
BSNOX G/KW HR (G/HP HR)	12.35 (9.21)	10.45 (7.79)	8.49 (6.33)	12.14 (9.05)
BSFC KG/KW HR (LB/HP HR)	.286 (.469)	.299 (.491)	.246 (.405)	.278 (.456)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.12 (21.62)
BSHC G/KW HR (G/HP HR)	.86 (.64)
BSCO G/KW HR (G/HP HR)	4.31 (3.22)
BSCO2 G/KW HR (G/HP HR)	840. (626.)
BSNOX G/KW HR (G/HP HR)	9.83 (7.33) Bag
BSFC KG/KW HR (LB/HP HR)	.265 (.436)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	11.41
	G/KWHR(G/HPHR)	.71 (.53)
	G/KG FUEL (G/LB FUEL)	2.67 (1.21)
	FILTER EFF.	97.7

TABLE B-7. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-16 RUN2
DATE 5/20/82
TIME
DYNO NO. 4

DIESEL EM-515-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-46. PCT , CVS-61. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(61.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.21 (2161.5)	61.24 (2162.3)	61.24 (2162.5)	61.24 (2162.3)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.63)	.05 (1.63)	.05 (1.63)	.05 (1.63)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	302.1 (10668.)	306.3 (10816.)	311.5 (10997.)	304.2 (10740.)
HC SAMPLE METER/RANGE/PPM	27.9/11/ 28.	27.4/11/ 27.	43.8/11/ 44.	23.1/11/ 23.
HC BCKGRD METER/RANGE/PPM	8.3/ 1/ 8.	8.9/ 1/ 9.	9.1/ 1/ 9.	9.2/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	87.6/13/ 88.	65.9/13/ 64.	34.3/13/ 32.	56.3/13/ 54.
CO BCKGRD METER/RANGE/PPM	2.3/13/ 2.	2.0/13/ 2.	1.6/13/ 1.	1.4/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	26.4/ 3/ .43	33.4/ 3/ .56	67.4/ 3/ 1.21	22.9/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.3/ 3/ .05	3.1/ 3/ .05	2.9/ 3/ .04	2.9/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	17.1/13/ 51.	19.8/13/ 59.	48.6/13/ 146.	17.0/13/ 51.
NOX BCKGRD METER/RANGE/PPM	1.1/ 2/ 1.	1.2/ 2/ 1.	.4/ 3/ 1.	1.5/ 2/ 2.
DILUTION FACTOR	30.22	23.69	10.99	35.38
HC CONCENTRATION PPM	20.	19.	36.	14.
CO CONCENTRATION PPM	83.	60.	29.	51.
CO2 CONCENTRATION PCT	.38	.51	1.17	.33
NOX CONCENTRATION PPM	50.3	58.2	144.8	49.6
HC MASS GRAMS	3.47	3.34	6.38	2.48
CO MASS GRAMS	29.32	21.43	10.53	18.06
CO2 MASS GRAMS	2119.4	2867.2	6677.7	1827.3
NOX MASS GRAMS	29.08	34.09	86.27	28.86
FUEL KG (LB)	.680 (1.50)	.909 (2.00)	2.097 (4.62)	.582 (1.28)
KW HR (HP HR)	2.14 (2.87)	2.92 (3.91)	8.83 (11.84)	2.04 (2.74)
BSHC G/KW HR (G/HP HR)	1.62 (1.21)	1.14 (.85)	.72 (.54)	1.21 (.90)
BSCO G/KW HR (G/HP HR)	13.70 (10.22)	7.35 (5.48)	1.19 (.89)	8.84 (6.59)
BSCO2 G/KW HR (G/HP HR)	990.30 (738.47)	983.36 (733.29)	756.33 (563.99)	894.32 (666.89)
BSNOX G/KW HR (G/HP HR)	13.59 (10.13)	11.69 (8.72)	9.77 (7.29)	14.12 (10.53)
BSFC KG/KW HR (LB/HP HR)	.318 (.522)	.312 (.513)	.238 (.391)	.285 (.468)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.93 (21.36)
BSHC G/KW HR (G/HP HR)	.98 (.73)
BSCO G/KW HR (G/HP HR)	4.98 (3.71)
BSCO2 G/KW HR (G/HP HR)	847. (632.)
BSNOX G/KW HR (G/HP HR)	11.19 (8.35)
BSFC KG/KW HR (LB/HP HR)	.268 (.441)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	11.42
	G/KWHR(G/HPHR)	.72 (.53)
	G/KG FUEL (G/LB FUEL)	2.67 (1.21)
	FILTER EFF.	97.0

TABLE B-7 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-16 RUN2
DATE 5/20/82
TIME
DYNO NO. 4

DIESEL EM-515-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-46. PCT , CVS-61. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(61.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.21 (2161.5)	61.24 (2162.3)	61.24 (2162.5)	61.24 (2162.3)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.63)	.05 (1.63)	.05 (1.63)	.05 (1.63)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	302.1 (10668.)	306.3 (10816.)	311.5 (10997.)	304.2 (10740.)
HC SAMPLE METER/RANGE/PPM	27.9/11/ 28.	27.4/11/ 27.	43.8/11/ 44.	23.1/11/ 23.
HC BCKGRD METER/RANGE/PPM	8.3/ 1/ 8.	8.9/ 1/ 9.	9.1/ 1/ 9.	9.2/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	87.6/13/ 88.	65.9/13/ 64.	34.3/13/ 32.	56.3/13/ 54.
CO BCKGRD METER/RANGE/PPM	2.3/13/ 2.	2.0/13/ 2.	1.6/13/ 1.	1.4/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	26.4/ 3/ .43	33.4/ 3/ .56	67.4/ 3/ 1.21	22.9/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.3/ 3/ .05	3.1/ 3/ .05	2.9/ 3/ .04	2.9/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	47.5/ 2/ 48.	53.6/ 2/ 54.	40.5/ 3/ 122.	46.3/ 2/ 46.
NOX BCKGRD METER/RANGE/PPM	1.1/ 2/ 1.	1.2/ 2/ 1.	.4/ 3/ 1.	1.5/ 2/ 2.
DILUTION FACTOR	30.22	23.69	10.99	35.38
HC CONCENTRATION PPM	20.	19.	36.	14.
CO CONCENTRATION PPM	83.	60.	29.	51.
CO2 CONCENTRATION PCT	.38	.51	1.17	.33
NOX CONCENTRATION PPM	46.4	52.5	120.4	44.8
HC MASS GRAMS	3.47	3.34	6.38	2.48
CO MASS GRAMS	29.32	21.43	10.53	18.06
CO2 MASS GRAMS	2119.4	2867.2	6677.7	1827.3
NOX MASS GRAMS	26.83	30.73	71.72	26.08
FUEL KG (LB)	.680 (1.50)	.909 (2.00)	2.097 (4.62)	.582 (1.28)
KW HR (HP HR)	2.14 (2.87)	2.92 (3.91)	8.83 (11.84)	2.04 (2.74)
BSHC G/KW HR (G/HP HR)	1.62 (1.21)	1.14 (.85)	.72 (.54)	1.21 (.90)
BSCO G/KW HR (G/HP HR)	13.70 (10.22)	7.35 (5.48)	1.19 (.89)	8.84 (6.59)
BSCO2 G/KW HR (G/HP HR)	990.30 (738.47)	983.36 (733.29)	756.33 (563.99)	894.32 (666.89)
BSNOX G/KW HR (G/HP HR)	12.54 (9.35)	10.54 (7.86)	8.12 (6.06)	12.77 (9.52)
BSFC KG/KW HR (LB/HP HR)	.318 (.522)	.312 (.513)	.238 (.391)	.285 (.468)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.93 (21.36)
BSHC G/KW HR (G/HP HR)	.98 (.73)
BSCO G/KW HR (G/HP HR)	4.98 (3.71)
BSCO2 G/KW HR (G/HP HR)	847. (632.)
BSNOX G/KW HR (G/HP HR)	9.75 (7.27) Bag
BSFC KG/KW HR (LB/HP HR)	.268 (.441)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	11.42
	G/KWHR(G/HPHR)	.72 (.53)
	G/KG FUEL (G/LB FUEL)	2.67 (1.21)
	FILTER EFF.	97.0

TABLE B-8. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-17 RUN2
DATE 5/20/82
TIME
DYNO NO. 4

DIESEL EM-515-F
BAG CART NO. 1

BAROMETER 741.43 MM HG(29.19 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-45. PCT , CVS-61. PCT
ABSOLUTE HUMIDITY 8.8 GM/KG(61.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.36 (2166.8)	61.35 (2166.2)	61.36 (2166.7)	61.37 (2166.9)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.64)	.05 (1.64)	.05 (1.64)	.05 (1.64)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	303.0 (10697.)	306.9 (10835.)	312.1 (11019.)	304.8 (10763.)
HC SAMPLE METER/RANGE/PPM	21.0/11/ 21.	25.4/11/ 25.	44.6/11/ 45.	21.8/11/ 22.
HC BCKGRD METER/RANGE/PPM	9.3/ 1/ 9.	9.0/ 1/ 9.	8.8/ 1/ 9.	9.0/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	64.0/13/ 62.	52.0/13/ 49.	31.4/13/ 29.	55.3/13/ 53.
CO BCKGRD METER/RANGE/PPM	.9/13/ 1.	.9/13/ 1.	.7/13/ 1.	.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	23.7/ 3/ .39	30.5/ 3/ .50	67.1/ 3/ 1.21	22.8/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05	3.3/ 3/ .05	3.4/ 3/ .05	3.0/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	17.1/13/ 51.	19.0/13/ 57.	47.7/13/ 143.	17.6/13/ 53.
NOX BCKGRD METER/RANGE/PPM	1.3/ 2/ 1.	1.3/ 2/ 1.	.4/ 3/ 1.	1.2/ 2/ 1.
DILUTION FACTOR	34.08	26.18	11.05	35.56
HC CONCENTRATION PPM	12.	17.	37.	13.
CO CONCENTRATION PPM	59.	47.	27.	51.
CO2 CONCENTRATION PCT	.34	.46	1.16	.32
NOX CONCENTRATION PPM	50.0	55.8	141.9	51.5
HC MASS GRAMS	2.09	2.95	6.58	2.30
CO MASS GRAMS	20.90	16.79	9.85	17.98
CO2 MASS GRAMS	1880.2	2561.7	6615.7	1813.1
NOX MASS GRAMS	28.95	32.74	84.66	30.02
FUEL KG (LB)	.600 (1.32)	.811 (1.79)	2.078 (4.58)	.577 (1.27)
KW HR (HP HR)	2.16 (2.89)	2.88 (3.86)	8.81 (11.81)	2.07 (2.78)
BSHC G/KW HR (G/HP HR)	.97 (.72)	1.03 (.77)	.75 (.56)	1.11 (.83)
BSCO G/KW HR (G/HP HR)	9.70 (7.23)	5.83 (4.35)	1.12 (.83)	8.67 (6.47)
BSCO2 G/KW HR (G/HP HR)	872.45 (650.59)	889.96 (663.64)	751.21 (560.18)	874.62 (652.20)
BSNOX G/KW HR (G/HP HR)	13.43 (10.02)	11.38 (8.48)	9.61 (7.17)	14.48 (10.80)
BSFC KG/KW HR (LB/HP HR)	.278 (.457)	.282 (.463)	.236 (.388)	.279 (.458)

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TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.91 (21.34)
BSHC G/KW HR (G/HP HR)	.88 (.65)
BSCO G/KW HR (G/HP HR)	4.12 (3.07)
BSCO2 G/KW HR (G/HP HR)	809. (603.)
BSNOX G/KW HR (G/HP HR)	11.08 (8.26)
BSFC KG/KW HR (LB/HP HR)	.256 (.420)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	10.85
	G/KWHR(G/HPHR)	.68 (.51)
	G/KG FUEL (G/LB FUEL)	2.67 (1.21)
	FILTER EFF.	97.5

TABLE B-8 (Cont'd). ENGINE EMISSION RESULTS - BAG NOx
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-17 RUN2
DATE 5/20/82
TIME
DYNO NO. 4

DIESEL EM-515-F
BAG CART NO. 1

BAROMETER 741.43 MM HG(29.19 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY, ENGINE-45. PCT , CVS-61. PCT
ABSOLUTE HUMIDITY 8.8 GM/KG(61.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.36 (2166.8)	61.35 (2166.2)	61.36 (2166.7)	61.37 (2166.9)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.64)	.05 (1.64)	.05 (1.64)	.05 (1.64)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	303.0 (10697.)	306.9 (10835.)	312.1 (11019.)	304.8 (10763.)
HC SAMPLE METER/RANGE/PPM	21.0/11/ 21.	25.4/11/ 25.	44.6/11/ 45.	21.8/11/ 22.
HC BCKGRD METER/RANGE/PPM	9.3/ 1/ 9.	9.0/ 1/ 9.	8.8/ 1/ 9.	9.0/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	64.0/13/ 62.	52.0/13/ 49.	31.4/13/ 29.	55.3/13/ 53.
CO BCKGRD METER/RANGE/PPM	.9/13/ 1.	.9/13/ 1.	.7/13/ 1.	.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	23.7/ 3/ .39	30.5/ 3/ .50	67.1/ 3/ 1.21	22.8/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05	3.3/ 3/ .05	3.4/ 3/ .05	3.0/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	45.8/ 2/ 46.	50.4/ 2/ 50.	41.1/ 3/ 123.	46.1/ 2/ 46.
NOX BCKGRD METER/RANGE/PPM	1.3/ 2/ 1.	1.3/ 2/ 1.	.4/ 3/ 1.	1.2/ 2/ 1.
DILUTION FACTOR	34.08	26.18	11.05	35.56
HC CONCENTRATION PPM	12.	17.	37.	13.
CO CONCENTRATION PPM	59.	47.	27.	51.
CO2 CONCENTRATION PCT	.34	.46	1.16	.32
NOX CONCENTRATION PPM	44.5	49.1	122.2	44.9
HC MASS GRAMS	2.09	2.95	6.58	2.30
CO MASS GRAMS	20.90	16.79	9.85	17.98
CO2 MASS GRAMS	1880.2	2561.7	6615.7	1813.1
NOX MASS GRAMS	25.80	28.84	72.93	26.19
FUEL KG (LB)	.600 (1.32)	.811 (1.79)	2.078 (4.58)	.577 (1.27)
KW HR (HP HR)	2.16 (2.89)	2.88 (3.86)	8.81 (11.81)	2.07 (2.78)
BSHC G/KW HR (G/HP HR)	.97 (.72)	1.03 (.77)	.75 (.56)	1.11 (.83)
BSCO G/KW HR (G/HP HR)	9.70 (7.23)	5.83 (4.35)	1.12 (.83)	8.67 (6.47)
BSCO2 G/KW HR (G/HP HR)	872.45 (650.59)	889.96 (663.64)	751.21 (560.18)	874.62 (652.20)
BSNOX G/KW HR (G/HP HR)	11.97 (8.93)	10.02 (7.47)	8.28 (6.18)	12.64 (9.42)
BSFC KG/KW HR (LB/HP HR)	.278 (.457)	.282 (.463)	.236 (.388)	.279 (.458)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.91 (21.34)
BSHC G/KW HR (G/HP HR)	.88 (.65)
BSCO G/KW HR (G/HP HR)	4.12 (3.07)
BSCO2 G/KW HR (G/HP HR)	809. (603.)
BSNOX G/KW HR (G/HP HR)	9.66 (7.21) Bag
BSFC KG/KW HR (LB/HP HR)	.256 (.420)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	
GRAMS/TEST	10.85
G/KWHR(G/HPHR)	.68 (.51)
G/KG FUEL (G/LB FUEL)	2.67 (1.21)
FILTER EFF.	97.5

TABLE B-9. TRANSIENT CYCLE STATISTICS AND MODAL EMISSION RATE SUMMARY

TRANSIENT CYCLE STATISTICS

TEST D3-14	Cold Cycle Speed	Cold Cycle Torque	Cold Cycle Power	Hot Cycle Speed	Hot Cycle Torque	Hot Cycle Power
Standard Error	58.8	4.2	4.5	52.2	3.9	4.3
Slope	0.9951	0.9671	1.0022	0.9951	0.9609	1.0001
Corr. Coef.	0.990	0.971	0.980	0.992	0.976	0.982
Intercept	15.4	-1.9	-1.2	16.4	0.3	-0.8
Points Used	1179	988	988	1179	998	998
Ref. Work (Dev. %)		21.77	(-1.23)		21.77	(-0.57)

TEST D3-16	Cold Cycle Speed	Cold Cycle Torque	Cold Cycle Power	Hot Cycle Speed	Hot Cycle Torque	Hot Cycle Power
Standard Error	59.6	4.3	4.9	54.3	4.4	5.1
Slope	0.9914	0.9840	1.0092	0.9917	0.9684	0.9981
Corr. Coef.	0.990	0.972	0.977	0.992	0.971	0.975
Intercept	16.3	-6.7	-2.3	18.7	-2.0	-1.8
Points Used	1179	990	990	1179	997	997
Ref. Work (Dev. %)		21.77	(-1.88)		21.77	(-1.99)

Note:
Units are as given in Federal Register Section 86.1341-84

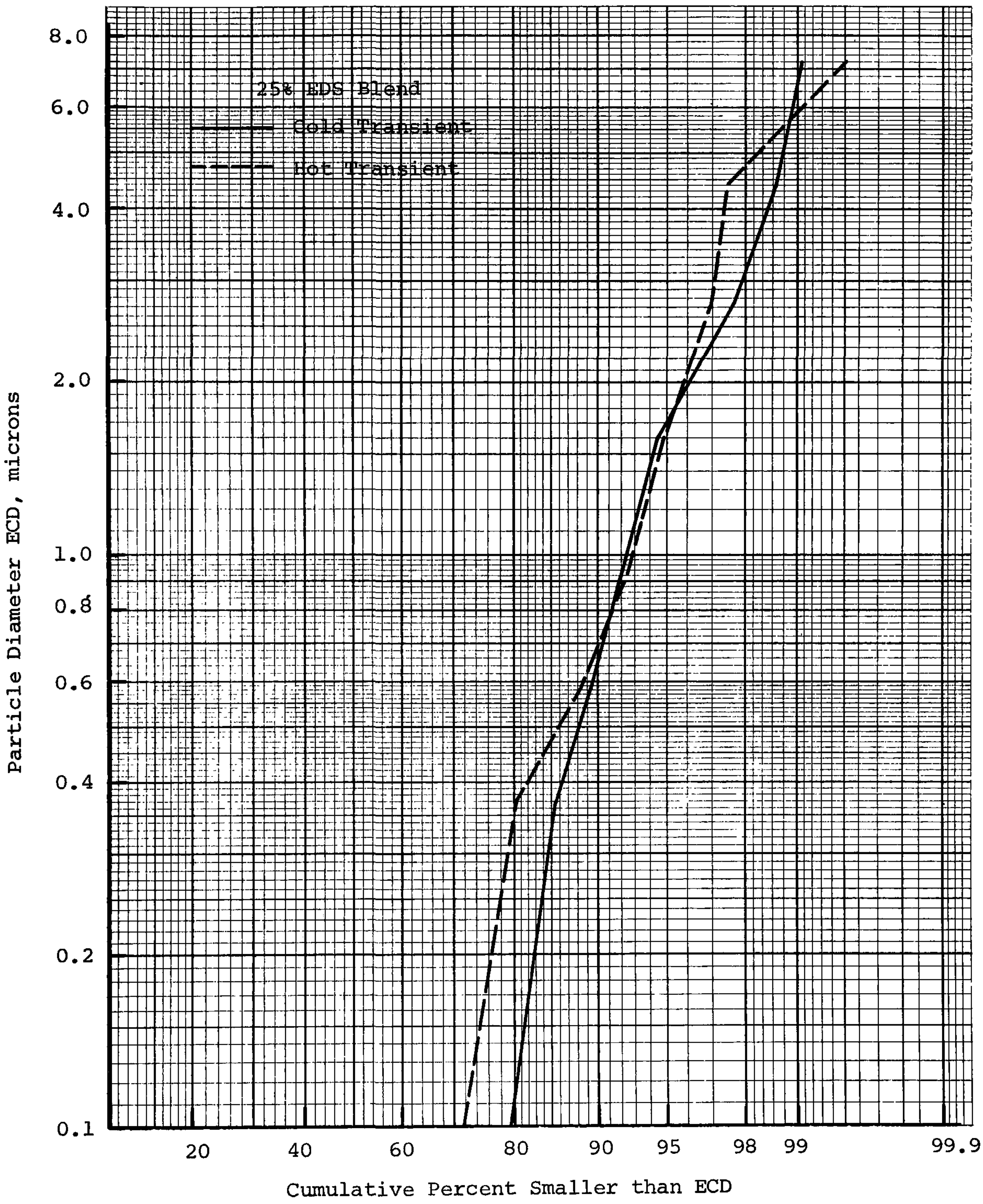

Figure B-1. Particle size distribution from transient operation of the Mack EM6-300 with 25 percent EDS Blend

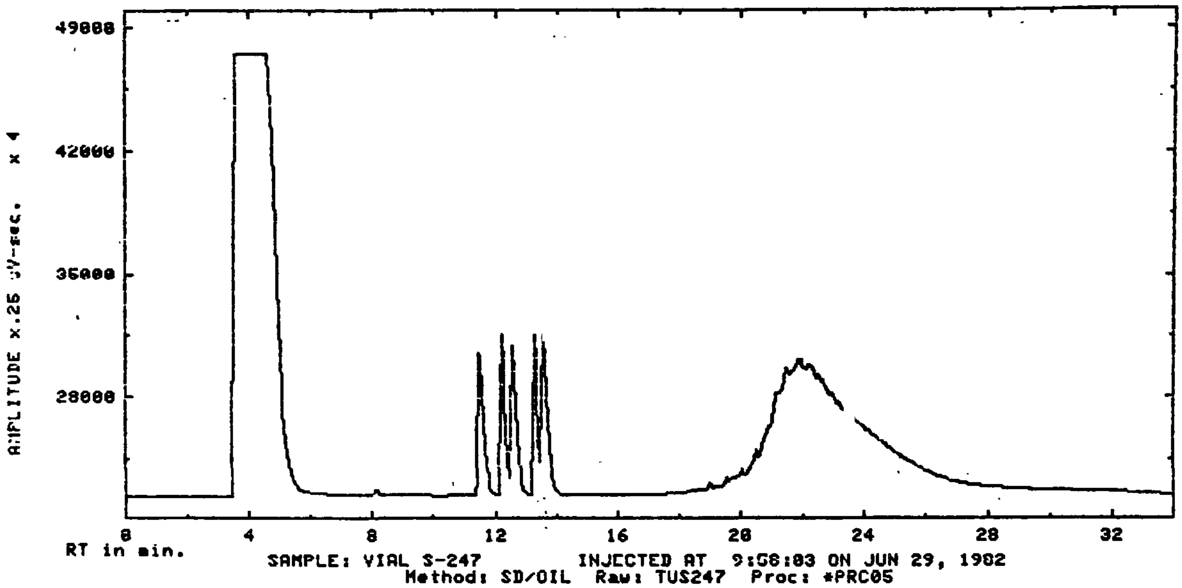

Figure B-2. Boiling Point Distribution of SOF derived from cold-start transient operation with EDS blend

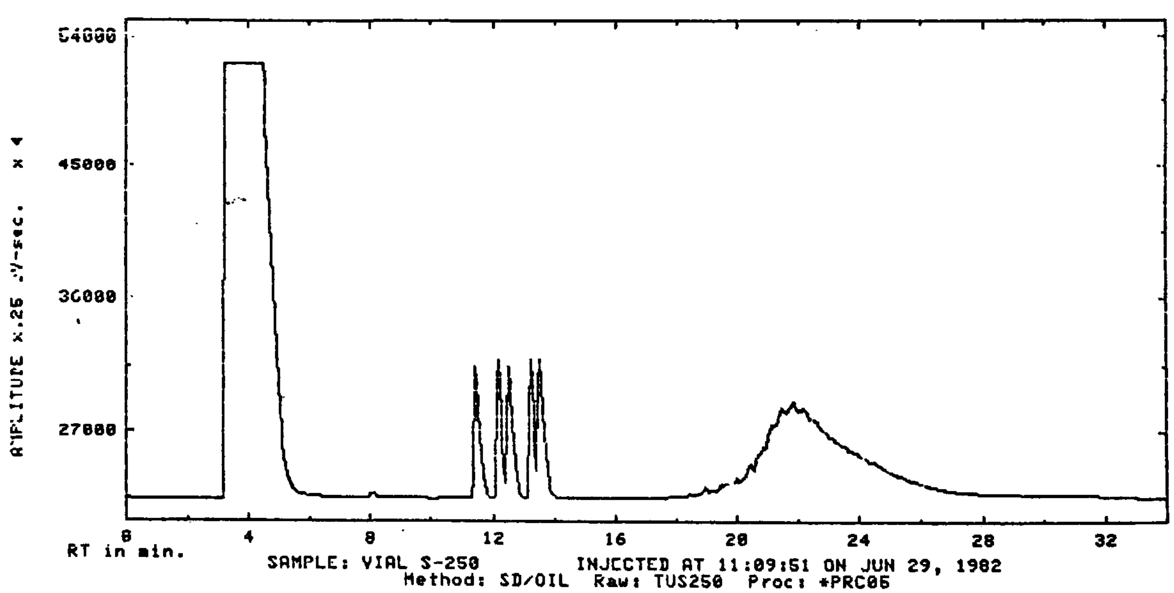

Figure B-3. Boiling Point Distribution of SOF derived from hot-start transient operation with EDS blend

APPENDIX C

TEST RESULTS WITH 25 PERCENT SRC-II (EM-511-F)

TABLE C-1. FULL LOAD PERFORMANCE DATA FROM THE MACK EM6-300 WITH (EM-511-F) 25 PERCENT SRC-II BLEND

Engine Speed	rpm	2100	1900	1700	1500	1260	1000
Torque	ft-lb	780	865	958	1021	1105	1047
	(N.m)	(1058)	(1173)	(1299)	(1384)	(1498)	(1420)
Power	hp	312	313	310	292	265	199
	(kW)	(233)	(234)	(231)	(218)	(198)	(148)
Fuel Rate	lb/hr	120.2	114.7	109.4	102.1	94.3	77.6
Fuel Temp.[a]	°F	99	101	102	103	103	104
Fuel Press.[b]	psig	21.0	20.2	19.5	19.3	18.2	16.0
Inlet Air Rate	lb/min	56.9	53.1	47.3	39.6	31.6	21.7
Inlet Air Depress.[c]	in H_2O	36.0	31.5	25.3	18.7	12.6	6.7
Inlet Air Temp.[d]	°F	75	75	75	75	76	77
Turbo Boost Press.	psig	22.5	22.5	21.2	19.0	17.0	17.2
Manifold Inlet Temp.	°F	120	122	123	122	120	116
Exhaust Back. Press.[e]	in Hg	2.6	2.1	1.8	1.2	0.8	0.4
Exhaust Temp.[e]	°F	826	841	882	953	1047	1148
Coolant Water Out	°F	188	191	192	191	192	196

Note: These data taken during run for power curve smoke - mode was held only long enough to record necessary data (approximately 2 minutes)

[a] Monitored at connection to injection pump
[b] Monitored after fuel filter
[c] Indicated reading using 4 inch tube metering section per 312GS148 of Mack
[d] Monitored upstream of metering section
[e] Indicated reading using 5 inch tube metering section per 312GS148 of Mack

TABLE C-2. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 SRC BLEND BAROMETER:28.90
TEST 03-01 FUEL: EM-511-F PROJECT: 05-5830-014 DATE: 05/29/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.017	3.34	74.	1.035	456.	654.	1.25	240.	35.	103.	64.	1
2	2	INTER / 1260.	30.	3.9	.061	6.83	74.	1.032	484.	807.	1.75	355.	96.	323.	239.	2
3	25	INTER / 1260.	377.	49.8	.190	7.55	74.	1.019	240.	185.	5.53	1290.	52.	78.	900.	3
4	50	INTER / 1260.	753.	99.3	.349	8.93	74.	1.005	228.	209.	8.21	1875.	62.	109.	1596.	4
5	75	INTER / 1260.	1130.	149.1	.531	11.84	74.	.999	160.	883.	9.66	1710.	57.	590.	1862.	5
6	100	INTER / 1260.	1505.	198.7	.707	14.41	74.	.996	76.	1708.	10.34	1605.	33.	1411.	2153.	6
7		IDLE / 650.	0.	.0	.016	3.20	74.	1.016	416.	543.	1.21	275.	31.	81.	68.	7
8	100	RATED / 2100.	1058.	232.7	.908	25.82	74.	1.009	162.	130.	7.27	765.	129.	198.	1923.	8
9	75	RATED / 2100.	785.	172.7	.685	22.12	74.	1.011	200.	108.	6.41	685.	135.	141.	1476.	9
10	50	RATED / 2100.	524.	115.1	.494	18.69	74.	1.016	218.	123.	5.61	555.	120.	132.	988.	10
11	25	RATED / 2100.	262.	57.6	.298	14.73	74.	1.018	246.	234.	4.24	440.	106.	200.	623.	11
12	2	RATED / 2100.	20.	4.5	.144	11.75	74.	1.025	384.	498.	2.46	300.	133.	345.	347.	12
13		IDLE / 650.	0.	.0	.017	3.23	74.	1.016	440.	543.	1.17	260.	37.	91.	73.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	GRAMS/KG-FUEL CO	GRAMS/KG-FUEL NOX	GRAMS/KW-HR HC	GRAMS/KW-HR CO	GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	34.00	98.29	60.94	************		******	.0053	.0700	.075	.985	.0064	21.6	.996	*****	.067	1
2	26.22	87.85	65.07	24.47	81.96	60.71	.0091	.0700	.129	.982	.0088	-2.5	1.002	.931	.080	2
3	4.52	6.79	78.76	1.04	1.56	18.09	.0255	.0700	.364	.953	.0257	1.0	1.003	.229	.080	3
4	2.96	5.18	76.19	.62	1.09	16.07	.0395	.0700	.564	.933	.0377	-4.5	1.006	.210	.080	4
5	1.78	18.50	58.40	.38	3.96	12.49	.0454	.0700	.648	.922	.0444	-2.2	1.015	.211	.080	5
6	.79	33.23	50.72	.17	7.10	10.84	.0496	.0700	.709	.917	.0477	-3.9	1.028	.208	.080	6
7	32.31	85.05	71.43	************		******	.0050	.0700	.072	.986	.0061	22.5	1.002	*****	.067	7
8	2.36	3.64	35.30	.55	.85	8.26	.0355	.0700	.508	.940	.0335	-5.7	1.092	.214	.080	8
9	3.28	3.43	35.92	.78	.82	8.55	.0313	.0700	.447	.946	.0296	-5.2	1.067	.223	.080	9
10	4.06	4.46	33.35	1.04	1.15	8.58	.0267	.0700	.381	.952	.0261	-2.3	1.045	.246	.080	10
11	5.96	11.17	34.89	1.85	3.47	10.83	.0204	.0700	.292	.963	.0199	-2.5	1.028	.302	.080	11
12	15.43	39.98	40.28	29.72	77.00	77.58	.0124	.0700	.177	.976	.0119	-3.5	1.018	1.891	.080	12
13	35.16	87.57	69.54	************		******	.0054	.0700	.078	.986	.0060	9.6	1.003	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- =	.932	GRAM/KW-HR	(.695	GRAM/BHP-HR)
BSCO ------- =	3.466	GRAM/KW-HR	(2.586	GRAM/BHP-HR (
BSNOX ------ =	11.334	GRAM/KW-HR	(8.455	GRAM/BHP-HR)
BSHC + BSNOX =	12.266	GRAM/KW-HR	(9.150	GRAM/BHP-HR)
CORR. BSFC - =	.234	KG/KW-HR	(.385	LBS/BHP-HR)

TABLE C-3. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 SRC BLEND BAROMETER:29.13
TEST-03-02 FUEL:EM-511-F PROJECT:05-5830-014 DATE:6/01/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.017	3.33	65.	1.012	376.	498.	1.21	300.	29.	78.	78.	1
2	2	INTER / 1260.	30.	3.9	.059	6.85	65.	1.014	424.	735.	1.71	360.	84.	291.	236.	2
3	25	INTER / 1260.	377.	49.8	.195	7.70	65.	1.002	208.	193.	5.61	1320.	45.	82.	914.	3
4	50	INTER / 1260.	753.	99.3	.349	9.06	65.	.988	208.	226.	8.41	1905.	55.	115.	1558.	4
5	75	INTER / 1260.	1130.	149.1	.531	11.62	65.	.982	156.	932.	9.77	1770.	55.	615.	1874.	5
6	100	INTER / 1260.	1512.	199.6	.704	14.49	65.	.980	76.	1680.	10.45	1665.	33.	1366.	2165.	6
7		IDLE / 650.	0.	.0	.018	3.30	65.	1.007	380.	532.	1.17	285.	33.	94.	83.	7
8	100	RATED / 2100.	1051.	231.2	.903	25.77	65.	.991	170.	130.	7.27	790.	134.	197.	1941.	8
9	75	RATED / 2100.	785.	172.7	.680	22.55	65.	.990	200.	108.	6.49	705.	132.	138.	1457.	9
10	50	RATED / 2100.	524.	115.1	.485	18.34	65.	.990	204.	123.	5.61	575.	110.	130.	981.	10
11	25	RATED / 2100.	262.	57.6	.299	14.69	65.	.989	228.	234.	4.38	455.	96.	194.	608.	11
12	2	RATED / 2100.	20.	4.5	.141	11.86	65.	.988	384.	509.	2.51	310.	128.	340.	334.	12
13		IDLE / 650.	0.	.0	.016	3.28	65.	.980	464.	543.	1.12	250.	37.	87.	64.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	GRAMS/KW-HR HC	GRAMS/KW-HR CO	GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	29.38	78.52	78.11	************		******	.0050	.0700	.072	.986	.0061	21.2	.986	*****	.067	1
2	23.63	82.35	66.71	21.23	73.98	59.94	.0087	.0700	.124	.983	.0086	-1.3	.990	.907	.080	2
3	3.87	6.99	78.13	.91	1.64	18.37	.0256	.0700	.365	.952	.0261	2.1	.991	.237	.080	3
4	2.64	5.47	74.36	.56	1.15	15.69	.0389	.0700	.556	.932	.0386	-.8	.996	.212	.080	4
5	1.71	19.30	58.77	.37	4.13	12.57	.0462	.0700	.660	.922	.0449	-2.8	1.003	.213	.080	5
6	.78	32.35	51.28	.17	6.85	10.85	.0490	.0700	.700	.917	.0481	-1.8	1.013	.209	.080	6
7	30.53	86.29	75.97	************		******	.0056	.0700	.079	.987	.0059	6.9	.988	*****	.067	7
8	2.48	3.64	35.82	.58	.85	8.40	.0354	.0700	.505	.940	.0335	-5.3	1.080	.217	.080	8
9	3.24	3.39	35.75	.77	.80	8.44	.0304	.0700	.435	.946	.0300	-1.3	1.058	.223	.080	9
10	3.80	4.46	33.68	.96	1.13	8.52	.0267	.0700	.382	.953	.0261	-2.4	1.039	.243	.080	10
11	5.36	10.82	33.96	1.67	3.37	10.57	.0205	.0700	.293	.962	.0205	.2	1.024	.304	.080	11
12	15.13	40.06	39.33	28.68	75.93	74.55	.0120	.0700	.172	.976	.0122	1.2	1.014	1.870	.080	12
13	38.50	90.99	66.98	************		******	.0049	.0700	.070	.987	.0057	17.7	.997	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- = .883 GRAM/KW-HR (.659 GRAM/BHP-HR)
BSCO ------- = 3.404 GRAM/KW-HR (2.539 GRAM/BHP-HR (
BSNOX ------ = 11.320 GRAM/KW-HR (8.445 GRAM/BHP-HR)
BSHC + BSNOX = 12.203 GRAM/KW-HR (9.103 GRAM/BHP-HR)
CORR. BSFC - = .235 KG/KW-HR (.387 LBS/BHP-HR)

TABLE C-4. REGULATED EMISSIONS SUMMARY FROM TRANSIENT FTP OPERATION OF THE MACK EM6-300 ENGINE WITH (EM-511) 25 PERCENT SRC-II BLEND

Cycle Type	Transient Emissions, g/kW-hr (g/hp-hr) HC	CO	NO_x Cont.	NO_x Bag	Part.	Cycle BSFC kg/kW-hr (lb/hp-hr)	Cycle Work kW-hr (hp-hr)
Cold Start	0.94 (0.70)	5.80 (4.33)	12.22 (9.11)	10.19 (7.60)	0.73 (0.54)	0.277 (0.455)	15.97 (21.41)
Hot Start	0.79 (0.59)	4.63 (3.45)	12.98 (9.68)	10.29 (7.67)	0.68 (0.51)	0.263 (0.432)	16.19 (21.71)
Transient Composite	0.81 (0.60)	4.80 (3.58)	12.87 (9.60)	10.28 (7.67)	0.69 (0.52)	0.265 (0.436)	16.16 (21.66)
Cold Start	1.04 (0.77)	6.01 (4.48)	12.09 (9.01)	9.81 (7.31)	0.78 (0.58)	0.279 (0.458)	16.10 (21.59)
Hot Start	0.83 (0.62)	4.84 (3.61)	11.68 (8.71)	8.77 (6.54)	0.63 (0.47)	0.264 (0.433)	16.18 (21.70)
Transient Composite	0.86 (0.64)	5.01 (3.74)	11.74 (8.76)	8.92 (6.65)	0.65 (0.48)	0.266 (0.438)	16.17 (21.68)

TABLE C-5. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-18 RUN2
DATE 5/28/82
TIME
DYNO NO. 4

DIESEL EM-511-F
BAG CART NO. 1

BAROMETER 735.08 MM HG(28.94 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-38. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 7.3 GM/KG(50.8 GRAINS/LB)
NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.61 (2140.2)	60.62 (2140.3)	60.61 (2140.1)	60.63 (2140.7)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.58)	.04 (1.58)	.04 (1.58)	.04 (1.58)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.1 (10563.)	303.2 (10706.)	308.2 (10884.)	301.1 (10633.)
HC SAMPLE METER/RANGE/PPM	31.4/11/ 31.	27.6/11/ 28.	42.5/11/ 43.	20.3/11/ 20.
HC BCKGRD METER/RANGE/PPM	8.6/ 1/ 9.	9.8/ 1/ 10.	10.0/ 1/ 10.	9.7/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	47.6/12/ 100.	36.2/12/ 73.	18.0/12/ 35.	33.0/12/ 66.
CO BCKGRD METER/RANGE/PPM	.5/12/ 1.	.3/12/ 1.	.3/12/ 1.	.4/12/ 1.
CO2 SAMPLE METER/RANGE/PCT	27.0/ 3/ .44	34.5/ 3/ .58	70.8/ 3/ 1.28	24.0/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.3/ 3/ .05	2.9/ 3/ .04	3.3/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	19.3/13/ 58.	21.1/13/ 63.	53.2/13/ 160.	19.2/13/ 58.
NOX BCKGRD METER/RANGE/PPM	1.0/ 2/ 1.	.8/ 2/ 1.	.3/ 3/ 1.	.9/ 2/ 1.
DILUTION FACTOR	29.42	22.85	10.40	33.61
HC CONCENTRATION PPM	23.	18.	33.	11.
CO CONCENTRATION PPM	96.	71.	33.	64.
CO2 CONCENTRATION PCT	.39	.53	1.23	.34
NOX CONCENTRATION PPM	57.0	62.5	158.9	56.7
HC MASS GRAMS	3.99	3.18	5.95	1.88
CO MASS GRAMS	33.58	24.95	11.75	22.38
CO2 MASS GRAMS	2156.4	2965.5	6968.1	1872.8
NOX MASS GRAMS	32.60	36.22	93.64	32.66
FUEL KG (LB)	.694 (1.53)	.942 (2.08)	2.188 (4.82)	.598 (1.32)
KW HR (HP HR)	2.10 (2.81)	2.94 (3.94)	8.85 (11.87)	2.08 (2.79)
BSHC G/KW HR (G/HP HR)	1.90 (1.42)	1.08 (.81)	.67 (.50)	.91 (.68)
BSCO G/KW HR (G/HP HR)	16.02 (11.95)	8.49 (6.33)	1.33 (.99)	10.76 (8.02)
BSCO2 G/KW HR (G/HP HR)	1029.12 (767.42)	1009.33 (752.65)	787.23 (587.04)	900.15 (671.24)
BSNOX G/KW HR (G/HP HR)	15.56 (11.60)	12.33 (9.19)	10.58 (7.89)	15.70 (11.71)
BSFC KG/KW HR (LB/HP HR)	.331 (.545)	.321 (.527)	.247 (.406)	.287 (.472)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.97 (21.41)
BSHC G/KW HR (G/HP HR)	.94 (.70)
BSCO G/KW HR (G/HP HR)	5.80 (4.33)
BSCO2 G/KW HR (G/HP HR)	875. (652.)
BSNOX G/KW HR (G/HP HR)	12.22 (9.11)
BSFC KG/KW HR (LB/HP HR)	.277 (.455)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	11.63
	G/KWHR(G/HPHR)	.73 (.54)
	G/KG FUEL (G/LB FUEL)	2.63 (1.19)
	FILTER EFF.	97.1

TABLE C-5 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-18 RUN2
DATE 5/28/82
TIME
DYNO NO. 4

DIESEL EM-511-F
BAG CART NO. 1

BAROMETER 735.08 MM HG(28.94 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-38. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 7.3 GM/KG(50.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.61 (2140.2)	60.62 (2140.3)	60.61 (2140.1)	60.63 (2140.7)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.58)	.04 (1.58)	.04 (1.58)	.04 (1.58)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.1 (10563.)	303.2 (10706.)	308.2 (10884.)	301.1 (10633.)
HC SAMPLE METER/RANGE/PPM	31.4/11/ 31.	27.6/11/ 28.	42.5/11/ 43.	20.3/11/ 20.
HC BCKGRD METER/RANGE/PPM	8.6/ 1/ 9.	9.8/ 1/ 10.	10.0/ 1/ 10.	9.7/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	47.6/12/ 100.	36.2/12/ 73.	18.0/12/ 35.	33.0/12/ 66.
CO BCKGRD METER/RANGE/PPM	.5/12/ 1.	.3/12/ 1.	.3/12/ 1.	.4/12/ 1.
CO2 SAMPLE METER/RANGE/PCT	27.0/ 3/ .44	34.5/ 3/ .58	70.8/ 3/ 1.28	24.0/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.3/ 3/ .05	2.9/ 3/ .04	3.3/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	47.4/ 2/ 47.	56.1/ 2/ 56.	43.0/ 3/ 129.	50.3/ 2/ 50.
NOX BCKGRD METER/RANGE/PPM	1.0/ 2/ 1.	.8/ 2/ 1.	.3/ 3/ 1.	.9/ 2/ 1.
DILUTION FACTOR	29.42	22.85	10.40	33.61
HC CONCENTRATION PPM	23.	18.	33.	11.
CO CONCENTRATION PPM	96.	71.	33.	64.
CO2 CONCENTRATION PCT	.39	.53	1.23	.34
NOX CONCENTRATION PPM	46.4	55.3	128.2	49.4
HC MASS GRAMS	3.99	3.18	5.95	1.88
CO MASS GRAMS	33.58	24.95	11.75	22.38
CO2 MASS GRAMS	2156.4	2965.5	6968.1	1872.8
NOX MASS GRAMS	26.56	32.09	75.56	28.46
FUEL KG (LB)	.694 (1.53)	.942 (2.08)	2.188 (4.82)	.598 (1.32)
KW HR (HP HR)	2.10 (2.81)	2.94 (3.94)	8.85 (11.87)	2.08 (2.79)
BSHC G/KW HR (G/HP HR)	1.90 (1.42)	1.08 (.81)	.67 (.50)	.91 (.68)
BSCO G/KW HR (G/HP HR)	16.02 (11.95)	8.49 (6.33)	1.33 (.99)	10.76 (8.02)
BSCO2 G/KW HR (G/HP HR)	1029.12 (767.42)	1009.33 (752.65)	787.23 (587.04)	900.15 (671.24)
BSNOX G/KW HR (G/HP HR)	12.68 (9.45)	10.92 (8.14)	8.54 (6.37)	13.68 (10.20)
BSFC KG/KW HR (LB/HP HR)	.331 (.545)	.321 (.527)	.247 (.406)	.287 (.472)

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TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.97 (21.41)
BSHC G/KW HR (G/HP HR)	.94 (.70)
BSCO G/KW HR (G/HP HR)	5.80 (4.33)
BSCO2 G/KW HR (G/HP HR)	875. (652.)
BSNOX G/KW HR (G/HP HR)	10.19 (7.60) Bag
BSFC KG/KW HR (LB/HP HR)	.277 (.455)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	11.63
G/KWHR(G/HPHR)	.73 (.54)
G/KG FUEL (G/LB FUEL)	2.63 (1.19)
FILTER EFF.	97.1

TABLE C-6. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-19 RUN2
DATE 5/28/82
TIME
DYNO NO. 4

DIESEL EM-511-F
BAG CART NO. 1

BAROMETER 735.33 MM HG(28.95 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-36. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 6.9 GM/KG(48.1 GRAINS/LB)   NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	305.0	297.9
TOT. BLOWER RATE SCMM (SCFM)	60.65 (2141.7)	60.65 (2141.5)	60.65 (2141.6)	60.64 (2141.1)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.59)	.05 (1.59)	.05 (1.59)	.05 (1.59)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.5 (10574.)	303.4 (10712.)	308.5 (10895.)	301.3 (10638.)
HC SAMPLE METER/RANGE/PPM	19.3/11/ 19.	23.9/11/ 24.	43.8/11/ 44.	21.0/11/ 21.
HC BCKGRD METER/RANGE/PPM	10.0/ 1/ 10.	9.2/ 1/ 9.	9.2/ 1/ 9.	9.0/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	35.6/12/ 72.	28.4/12/ 56.	16.4/12/ 32.	31.7/12/ 63.
CO BCKGRD METER/RANGE/PPM	.6/12/ 1.	.6/12/ 1.	.6/12/ 1.	.4/12/ 1.
CO2 SAMPLE METER/RANGE/PCT	25.6/ 3/ .42	32.4/ 3/ .54	69.7/ 3/ 1.26	23.8/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.0/ 3/ .05	3.8/ 3/ .06	3.2/ 3/ .05	3.3/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	6.2/14/ 62.	7.1/14/ 71.	16.8/14/ 168.	6.3/14/ 63.
NOX BCKGRD METER/RANGE/PPM	.9/ 2/ 1.	.8/ 2/ 1.	.3/ 3/ 1.	.9/ 2/ 1.
DILUTION FACTOR	31.38	24.52	10.59	33.92
HC CONCENTRATION PPM	10.	15.	35.	12.
CO CONCENTRATION PPM	69.	54.	29.	61.
CO2 CONCENTRATION PCT	.37	.48	1.21	.34
NOX CONCENTRATION PPM	61.4	69.8	167.3	62.0
HC MASS GRAMS	1.65	2.64	6.31	2.13
CO MASS GRAMS	24.08	18.94	10.49	21.42
CO2 MASS GRAMS	2048.3	2681.1	6856.1	1862.8
NOX MASS GRAMS	35.16	40.50	98.69	35.70
FUEL KG (LB)	.653 (1.44)	.849 (1.87)	2.153 (4.75)	.595 (1.31)
KW HR (HP HR)	2.21 (2.97)	3.01 (4.04)	8.88 (11.91)	2.08 (2.79)
BSHC G/KW HR (G/HP HR)	.75 (.56)	.88 (.65)	.71 (.53)	1.02 (.76)
BSCO G/KW HR (G/HP HR)	10.87 (8.11)	6.29 (4.69)	1.18 (.88)	10.30 (7.68)
BSCO2 G/KW HR (G/HP HR)	924.85 (689.66)	889.97 (663.65)	771.97 (575.66)	895.38 (667.69)
BSNOX G/KW HR (G/HP HR)	15.88 (11.84)	13.44 (10.03)	11.11 (8.29)	17.16 (12.80)
BSFC KG/KW HR (LB/HP HR)	.295 (.485)	.282 (.464)	.242 (.399)	.286 (.470)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.19 (21.71)
BSHC G/KW HR (G/HP HR)	.79 (.59)
BSCO G/KW HR (G/HP HR)	4.63 (3.45)
BSCO2 G/KW HR (G/HP HR)	831. (619.)
BSNOX G/KW HR (G/HP HR)	12.98 (9.68)
BSFC KG/KW HR (LB/HP HR)	.263 (.432)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	10.99
	G/KWHR(G/HPHR)	.68 (.51)
	G/KG FUEL (G/LB FUEL)	2.59 (1.17)
	FILTER EFF.	97.7

TABLE C-6 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-19 RUN2
DATE 5/28/82
TIME
DYNO NO. 4

DIESEL EM-511-F
BAG CART NO. 1

BAROMETER 735.33 MM HG(28.95 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-36. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 6.9 GM/KG(48.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	299.9	305.0	297.9
TOT. BLOWER RATE SCMM (SCFM)	60.65 (2141.7)	60.65 (2141.5)	60.65 (2141.6)	60.64 (2141.1)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.59)	.05 (1.59)	.05 (1.59)	.05 (1.59)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.5 (10574.)	303.4 (10712.)	308.5 (10895.)	301.3 (10638.)
HC SAMPLE METER/RANGE/PPM	19.3/11/ 19.	23.9/11/ 24.	43.8/11/ 44.	21.0/11/ 21.
HC BCKGRD METER/RANGE/PPM	10.0/ 1/ 10.	9.2/ 1/ 9.	9.2/ 1/ 9.	9.0/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	35.6/12/ 72.	28.4/12/ 56.	16.4/12/ 32.	31.7/12/ 63.
CO BCKGRD METER/RANGE/PPM	.6/12/ 1.	.6/12/ 1.	.6/12/ 1.	.4/12/ 1.
CO2 SAMPLE METER/RANGE/PCT	25.6/ 3/ .42	32.4/ 3/ .54	69.7/ 3/ 1.26	23.8/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.0/ 3/ .05	3.8/ 3/ .06	3.2/ 3/ .05	3.3/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	51.7/ 2/ 52.	57.0/ 2/ 57.	43.6/ 3/ 131.	49.7/ 2/ 50.
NOX BCKGRD METER/RANGE/PPM	.9/ 2/ 1.	.8/ 2/ 1.	.3/ 3/ 1.	.9/ 2/ 1.
DILUTION FACTOR	31.38	24.52	10.59	33.92
HC CONCENTRATION PPM	10.	15.	35.	12.
CO CONCENTRATION PPM	69.	54.	29.	61.
CO2 CONCENTRATION PCT	.37	.48	1.21	.34
NOX CONCENTRATION PPM	50.8	56.2	130.0	48.8
HC MASS GRAMS	1.65	2.64	6.31	2.13
CO MASS GRAMS	24.08	18.94	10.49	21.42
CO2 MASS GRAMS	2048.3	2681.1	6856.1	1862.8
NOX MASS GRAMS	29.11	32.62	76.70	28.13
FUEL KG (LB)	.653 (1.44)	.849 (1.87)	2.153 (4.75)	.595 (1.31)
KW HR (HP HR)	2.21 (2.97)	3.01 (4.04)	8.88 (11.91)	2.08 (2.79)
BSHC G/KW HR (G/HP HR)	.75 (.56)	.88 (.65)	.71 (.53)	1.02 (.76)
BSCO G/KW HR (G/HP HR)	10.87 (8.11)	6.29 (4.69)	1.18 (.88)	10.30 (7.68)
BSCO2 G/KW HR (G/HP HR)	924.85 (689.66)	889.97 (663.65)	771.97 (575.66)	895.38 (667.69)
BSNOX G/KW HR (G/HP HR)	13.14 (9.80)	10.83 (8.08)	8.64 (6.44)	13.52 (10.08)
BSFC KG/KW HR (LB/HP HR)	.295 (.485)	.282 (.464)	.242 (.399)	.286 (.470)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.19 (21.71)
BSHC G/KW HR (G/HP HR)	.79 (.59)
BSCO G/KW HR (G/HP HR)	4.63 (3.45)
BSCO2 G/KW HR (G/HP HR)	831. (619.)
BSNOX G/KW HR (G/HP HR)	10.29 (7.67) Bag
BSFC KG/KW HR (LB/HP HR)	.263 (.432)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	10.99
	G/KWHR(G/HPHR)	.68 (.51)
	G/KG FUEL (G/LB FUEL)	2.59 (1.17)
	FILTER EFF.	97.7

TABLE C-7. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-23 RUN
DATE 5/31/82
TIME
DYNO NO. 4

DIESEL EM-511-F
BAG CART NO. 1

BAROMETER 737.36 MM HG(29.03 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-55. PCT , CVS-53. PCT
ABSOLUTE HUMIDITY 10.5 GM/KG(73.7 GRAINS/LB)   NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.9
TOT. BLOWER RATE SCMM (SCFM)	61.10 (2157.4)	61.09 (2157.2)	61.12 (2158.0)	61.07 (2156.4)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.61)	.05 (1.61)	.05 (1.61)	.05 (1.61)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.5 (10648.)	305.6 (10790.)	310.8 (10975.)	303.4 (10714.)
HC SAMPLE METER/RANGE/PPM	35.4/11/ 35.	29.4/11/ 29.	43.7/11/ 44.	25.5/11/ 25.
HC BCKGRD METER/RANGE/PPM	9.7/ 1/ 10.	10.1/ 1/ 10.	11.0/ 1/ 11.	10.9/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	49.5/12/ 105.	78.1/13/ 77.	41.0/13/ 38.	69.4/13/ 67.
CO BCKGRD METER/RANGE/PPM	.7/12/ 1.	1.8/13/ 2.	2.1/13/ 2.	1.9/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	27.5/ 3/ .45	35.1/ 3/ .59	70.7/ 3/ 1.28	24.1/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.3/ 3/ .05	3.3/ 3/ .05	3.3/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	5.5/14/ 55.	6.6/14/ 66.	16.3/14/ 163.	5.6/14/ 56.
NOX BCKGRD METER/RANGE/PPM	1.5/ 2/ 2.	2.2/ 2/ 2.	3.2/ 2/ 3.	2.0/ 2/ 2.
DILUTION FACTOR	28.81	22.41	10.42	33.41
HC CONCENTRATION PPM	26.	20.	34.	15.
CO CONCENTRATION PPM	101.	73.	35.	64.
CO2 CONCENTRATION PCT	.40	.54	1.23	.34
NOX CONCENTRATION PPM	53.5	63.7	160.5	53.6
HC MASS GRAMS	4.52	3.49	6.06	2.61
CO MASS GRAMS	35.36	26.09	12.64	22.68
CO2 MASS GRAMS	2222.5	3017.0	7014.8	1896.8
NOX MASS GRAMS	30.88	37.21	95.41	31.13
FUEL KG (LB)	.716 (1.58)	.959 (2.11)	2.203 (4.86)	.606 (1.34)
KW HR (HP HR)	2.14 (2.87)	2.98 (4.00)	8.91 (11.95)	2.07 (2.77)
BSHC G/KW HR (G/HP HR)	2.11 (1.58)	1.17 (.87)	.68 (.51)	1.26 (.94)
BSCO G/KW HR (G/HP HR)	16.52 (12.32)	8.75 (6.52)	1.42 (1.06)	10.98 (8.19)
BSCO2 G/KW HR (G/HP HR)	1038.49 (774.40)	1011.48 (754.26)	787.20 (587.01)	918.29 (684.77)
BSNOX G/KW HR (G/HP HR)	14.43 (10.76)	12.48 (9.30)	10.71 (7.98)	15.07 (11.24)
BSFC KG/KW HR (LB/HP HR)	.335 (.550)	.321 (.528)	.247 (.406)	.293 (.482)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.10 (21.59)
BSHC G/KW HR (G/HP HR)	1.04 (.77)
BSCO G/KW HR (G/HP HR)	6.01 (4.48)
BSCO2 G/KW HR (G/HP HR)	879. (655.)
BSNOX G/KW HR (G/HP HR)	12.09 (9.01)
BSFC KG/KW HR (LB/HP HR)	.279 (.458)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	12.54
G/KWHR(G/HPHR)	.78 (.58)
G/KG FUEL (G/LB FUEL)	2.80 (1.27)
FILTER EFF.	97.1

TABLE C-7 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-23 RUN
DATE 5/31/82
TIME
DYNO NO. 4

DIESEL EM-511-F
BAG CART NO. 1

BAROMETER 737.36 MM HG(29.03 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-55. PCT , CVS-53. PCT
ABSOLUTE HUMIDITY 10.5 GM/KG(73.7 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.9
TOT. BLOWER RATE SCMM (SCFM)	61.10 (2157.4)	61.09 (2157.2)	61.12 (2158.0)	61.07 (2156.4)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.61)	.05 (1.61)	.05 (1.61)	.05 (1.61)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.5 (10648.)	305.6 (10790.)	310.8 (10975.)	303.4 (10714.)
HC SAMPLE METER/RANGE/PPM	35.4/11/ 35.	29.4/11/ 29.	43.7/11/ 44.	25.5/11/ 25.
HC BCKGRD METER/RANGE/PPM	9.7/ 1/ 10.	10.1/ 1/ 10.	11.0/ 1/ 11.	10.9/ 1/ 11.
CO SAMPLE METER/RANGE/PPM	49.5/12/ 105.	78.1/13/ 77.	41.0/13/ 38.	69.4/13/ 67.
CO BCKGRD METER/RANGE/PPM	.7/12/ 1.	1.8/13/ 2.	2.1/13/ 2.	1.9/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	27.5/ 3/ .45	35.1/ 3/ .59	70.7/ 3/ 1.28	24.1/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.3/ 3/ .05	3.3/ 3/ .05	3.3/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	44.3/ 2/ 44.	51.0/ 2/ 51.	46.2/ 3/ 139.	43.2/ 2/ 43.
NOX BCKGRD METER/RANGE/PPM	1.5/ 2/ 2.	2.2/ 2/ 2.	3.2/ 2/ 3.	2.0/ 2/ 2.
DILUTION FACTOR	28.81	22.41	10.42	33.41
HC CONCENTRATION PPM	26.	20.	34.	15.
CO CONCENTRATION PPM	101.	73.	35.	64.
CO2 CONCENTRATION PCT	.40	.54	1.23	.34
NOX CONCENTRATION PPM	42.9	48.9	135.7	41.3
HC MASS GRAMS	4.52	3.49	6.06	2.61
CO MASS GRAMS	35.36	26.09	12.64	22.68
CO2 MASS GRAMS	2222.5	3017.0	7014.8	1896.8
NOX MASS GRAMS	24.71	28.58	80.66	23.94
FUEL KG (LB)	.716 (1.58)	.959 (2.11)	2.203 (4.86)	.606 (1.34)
KW HR (HP HR)	2.14 (2.87)	2.98 (4.00)	8.91 (11.95)	2.07 (2.77)
BSHC G/KW HR (G/HP HR)	2.11 (1.58)	1.17 (.87)	.68 (.51)	1.26 (.94)
BSCO G/KW HR (G/HP HR)	16.52 (12.32)	8.75 (6.52)	1.42 (1.06)	10.98 (8.19)
BSCO2 G/KW HR (G/HP HR)	1038.49 (774.40)	1011.48 (754.26)	787.20 (587.01)	918.29 (684.77)
BSNOX G/KW HR (G/HP HR)	11.55 (8.61)	9.58 (7.14)	9.05 (6.75)	11.59 (8.64)
BSFC KG/KW HR (LB/HP HR)	.335 (.550)	.321 (.528)	.247 (.406)	.293 (.482)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.10 (21.59)
BSHC G/KW HR (G/HP HR)	1.04 (.77)
BSCO G/KW HR (G/HP HR)	6.01 (4.48)
BSCO2 G/KW HR (G/HP HR)	879. (655.)
BSNOX G/KW HR (G/HP HR)	9.81 (7.31) Bag
BSFC KG/KW HR (LB/HP HR)	.279 (.458)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	12.54
	G/KWHR(G/HPHR)	.78 (.58)
	G/KG FUEL (G/LB FUEL)	2.80 (1.27)
	FILTER EFF.	97.1

TABLE C-8. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-24 RUN
DATE 5/31/82
TIME
DYNO NO. 4

DIESEL EM-511-F
BAG CART NO. 1

BAROMETER 737.62 MM HG(29.04 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-58. PCT , CVS-42. PCT
ABSOLUTE HUMIDITY 11.1 GM/KG(77.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	300.0	305.0	297.9
TOT. BLOWER RATE SCMM (SCFM)	61.11 (2157.8)	61.09 (2157.2)	61.12 (2158.1)	61.10 (2157.5)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.75)	.05 (1.75)	.05 (1.75)	.05 (1.75)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.6 (10650.)	305.7 (10795.)	310.9 (10979.)	303.6 (10721.)
HC SAMPLE METER/RANGE/PPM	23.1/11/ 23.	26.2/11/ 26.	44.1/11/ 44.	22.4/11/ 22.
HC BCKGRD METER/RANGE/PPM	10.9/ 1/ 11.	10.9/ 1/ 11.	10.2/ 1/ 10.	10.1/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	77.1/13/ 76.	60.9/13/ 58.	37.3/13/ 35.	65.1/13/ 63.
CO BCKGRD METER/RANGE/PPM	1.5/13/ 1.	1.6/13/ 1.	1.3/13/ 1.	1.7/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	24.4/ 3/ .40	32.0/ 3/ .53	69.8/ 3/ 1.26	23.8/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.2/ 3/ .05	3.0/ 3/ .05	3.0/ 3/ .05	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	5.2/14/ 52.	6.1/14/ 61.	15.8/14/ 158.	5.5/14/ 55.
NOX BCKGRD METER/RANGE/PPM	1.0/ 2/ 1.	.7/ 2/ 1.	.5/ 3/ 2.	.7/ 2/ 1.
DILUTION FACTOR	32.93	24.83	10.57	33.91
HC CONCENTRATION PPM	12.	16.	35.	13.
CO CONCENTRATION PPM	73.	56.	32.	60.
CO2 CONCENTRATION PCT	.35	.49	1.22	.34
NOX CONCENTRATION PPM	50.6	60.3	156.8	53.9
HC MASS GRAMS	2.17	2.78	6.26	2.20
CO MASS GRAMS	25.64	19.81	11.67	21.24
CO2 MASS GRAMS	1930.9	2728.0	6936.9	1894.0
NOX MASS GRAMS	29.20	35.25	93.24	31.32
FUEL KG (LB)	.618 (1.36)	.865 (1.91)	2.179 (4.80)	.604 (1.33)
KW HR (HP HR)	2.16 (2.89)	2.98 (4.00)	8.94 (11.99)	2.10 (2.82)
BSHC G/KW HR (G/HP HR)	1.01 (.75)	.93 (.69)	.70 (.52)	1.05 (.78)
BSCO G/KW HR (G/HP HR)	11.90 (8.87)	6.64 (4.95)	1.30 (.97)	10.10 (7.53)
BSCO2 G/KW HR (G/HP HR)	895.98 (668.13)	914.56 (681.99)	775.85 (578.55)	900.66 (671.62)
BSNOX G/KW HR (G/HP HR)	13.55 (10.10)	11.82 (8.81)	10.43 (7.78)	14.89 (11.11)
BSFC KG/KW HR (LB/HP HR)	.287 (.471)	.290 (.477)	.244 (.401)	.287 (.472)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.18 (21.70)
BSHC G/KW HR (G/HP HR)	.83 (.62)
BSCO G/KW HR (G/HP HR)	4.84 (3.61)
BSCO2 G/KW HR (G/HP HR)	834. (622.)
BSNOX G/KW HR (G/HP HR)	11.68 (8.71)
BSFC KG/KW HR (LB/HP HR)	.264 (.433)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	10.23
	G/KWHR(G/HPHR)	.63 (.47)
	G/KG FUEL (G/LB FUEL)	2.40 (1.09)
	FILTER EFF.	97.5

TABLE C-8. (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) 1-6
CVS NO. 11

TEST NO.D3-24 RUN
DATE 5/31/82
TIME
DYNO NO. 4

DIESEL EM-511-F
BAG CART NO. 1

BAROMETER 737.62 MM HG(29.04 IN HG)
DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)

RELATIVE HUMIDITY , ENGINE-58. PCT , CVS-42. PCT
ABSOLUTE HUMIDITY 11.1 GM/KG(77.8 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	300.0	305.0	297.9
TOT. BLOWER RATE SCMM (SCFM)	61.11 (2157.8)	61.09 (2157.2)	61.12 (2158.1)	61.10 (2157.5)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.75)	.05 (1.75)	.05 (1.75)	.05 (1.75)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.6 (10650.)	305.7 (10795.)	310.9 (10979.)	303.6 (10721.)
HC SAMPLE METER/RANGE/PPM	23.1/11/ 23.	26.2/11/ 26.	44.1/11/ 44.	22.4/11/ 22.
HC BCKGRD METER/RANGE/PPM	10.9/ 1/ 11.	10.9/ 1/ 11.	10.2/ 1/ 10.	10.1/ 1/ 10.
CO SAMPLE METER/RANGE/PPM	77.1/13/ 76.	60.9/13/ 58.	37.3/13/ 35.	65.1/13/ 63.
CO BCKGRD METER/RANGE/PPM	1.5/13/ 1.	1.6/13/ 1.	1.3/13/ 1.	1.7/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	24.4/ 3/ .40	32.0/ 3/ .53	69.8/ 3/ 1.26	23.8/ 3/ .39
CO2 BCKGRD METER/RANGE/PCT	3.2/ 3/ .05	3.0/ 3/ .05	3.0/ 3/ .05	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	45.2/ 2/ 45.	49.9/ 2/ 50.	35.4/ 3/ 106.	44.1/ 2/ 44.
NOX BCKGRD METER/RANGE/PPM	1.0/ 2/ 1.	.7/ 2/ 1.	.5/ 3/ 2.	.7/ 2/ 1.
DILUTION FACTOR	32.93	24.83	10.57	33.91
HC CONCENTRATION PPM	12.	16.	35.	13.
CO CONCENTRATION PPM	73.	56.	32.	60.
CO2 CONCENTRATION PCT	.35	.49	1.22	.34
NOX CONCENTRATION PPM	44.2	49.2	104.8	43.4
HC MASS GRAMS	2.17	2.78	6.26	2.20
CO MASS GRAMS	25.64	19.81	11.67	21.24
CO2 MASS GRAMS	1930.9	2728.0	6936.9	1894.0
NOX MASS GRAMS	25.51	28.78	62.34	25.21
FUEL KG (LB)	.618 (1.36)	.865 (1.91)	2.179 (4.80)	.604 (1.33)
KW HR (HP HR)	2.16 (2.89)	2.98 (4.00)	8.94 (11.99)	2.10 (2.82)
BSHC G/KW HR (G/HP HR)	1.01 (.75)	.93 (.69)	.70 (.52)	1.05 (.78)
BSCO G/KW HR (G/HP HR)	11.90 (8.87)	6.64 (4.95)	1.30 (.97)	10.10 (7.53)
BSCO2 G/KW HR (G/HP HR)	895.98 (668.13)	914.56 (681.99)	775.85 (578.55)	900.66 (671.62)
BSNOX G/KW HR (G/HP HR)	11.84 (8.83)	9.65 (7.20)	6.97 (5.20)	11.99 (8.94)
BSFC KG/KW HR (LB/HP HR)	.287 (.471)	.290 (.477)	.244 (.401)	.287 (.472)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.18 (21.70)
BSHC G/KW HR (G/HP HR)	.83 (.62)
BSCO G/KW HR (G/HP HR)	4.84 (3.61)
BSCO2 G/KW HR (G/HP HR)	834. (622.)
BSNOX G/KW HR (G/HP HR)	8.77 (6.54) Bag
BSFC KG/KW HR (LB/HP HR)	.264 (.433)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	10.23
	G/KWHR (G/HPHR)	.63 (.47)
	G/KG FUEL (G/LB FUEL)	2.40 (1.09)
	FILTER EFF.	97.5

TABLE C-9. TRANSIENT CYCLE STATISTICS AND MODAL EMISSION RATE SUMMARY

TRANSIENT CYCLE STATISTICS

TEST D3-18	Cold Cycle			Hot Cycle		
	Speed	Torque	Power	Speed	Torque	Power
Standard Error	50.6	4.4	4.9	46.4	4.1	4.6
Slope	0.9977	0.9608	0.9949	0.9991	0.9529	0.9972
Corr. Coef.	0.993	0.968	0.976	0.994	5.7	0.979
Intercept	11.0	-0.3	-1.0	13.5	993	-0.4
Points Used	1179	981	981	1179	21.77	993
Ref. Work (Dev. %)		21.77	(-1.68)			(-0.27)

TEST D-23	Cold Cycle			Hot Cycle		
	Speed	Torque	Power	Speed	Torque	Power
Standard Error	48.5	4.7	5.2	44.2	4.0	4.6
Slope	1.0011	0.9648	1.0013	1.0001	0.9699	1.0068
Corr. Coef.	0.993	0.964	0.974	0.995	.975	0.980
Intercept	8.0	-1.3	-1.1	12.5	0.4	-1.1
Points Used	1179	988	988	1179	996	996
Ref. Work (Dev. %)		21.77	(-0.84)		21.77	(-0.32)

Note:
Units are as given in Federal Register Section 86.1341-84

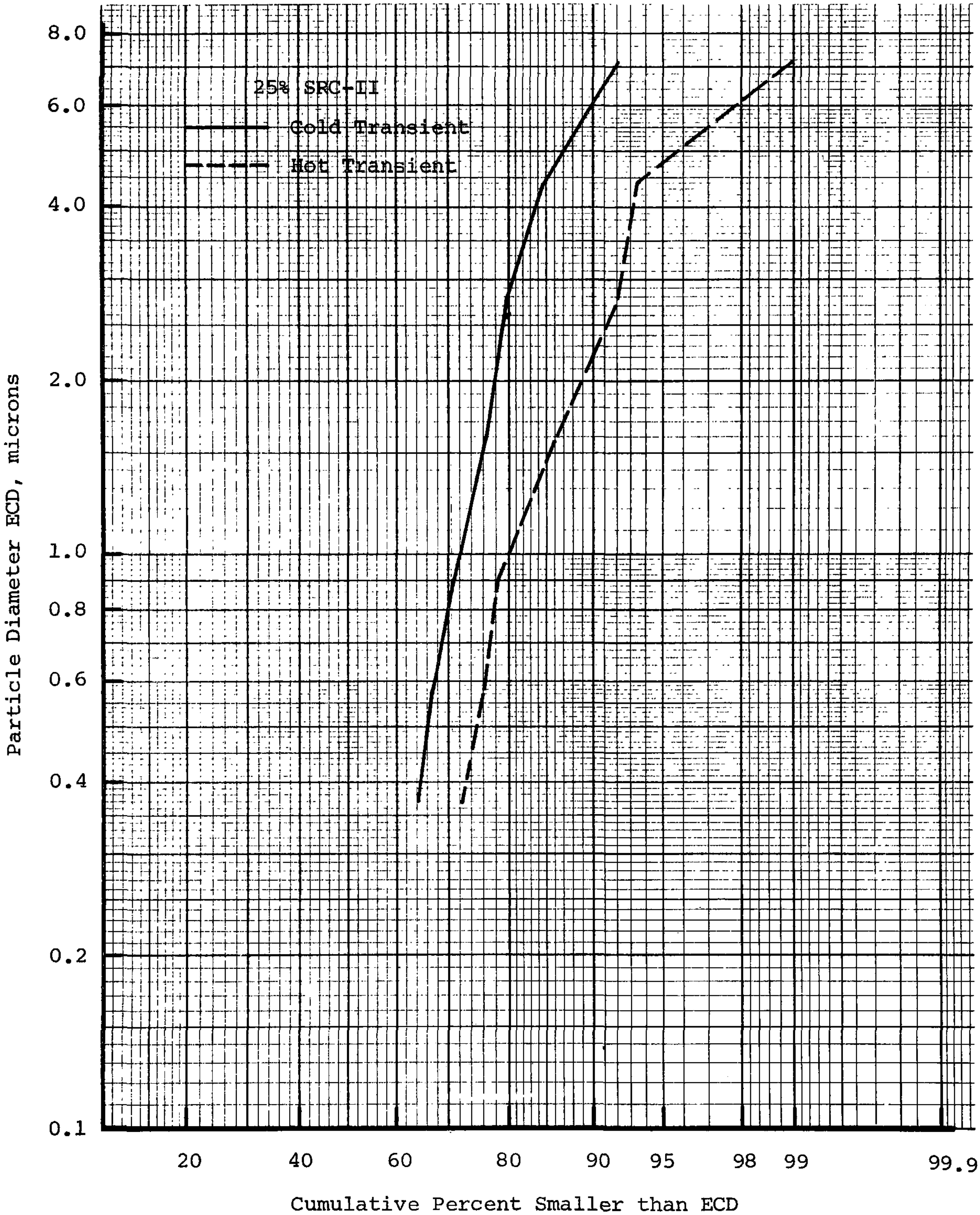

Figure C-1. Particle size distribution from transient operation of the Mack EM6-300 with 25 percent SRC-II Blend

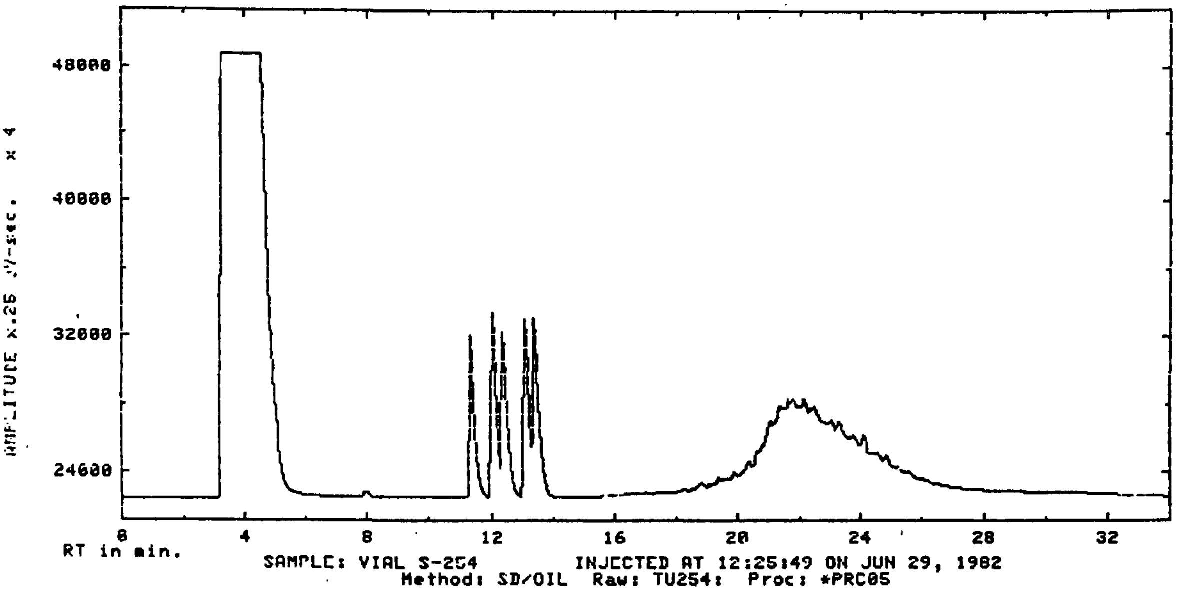

Figure C-2. Boiling Point Distribution of SOF derived from cold-start transient operation with SRC-II blend

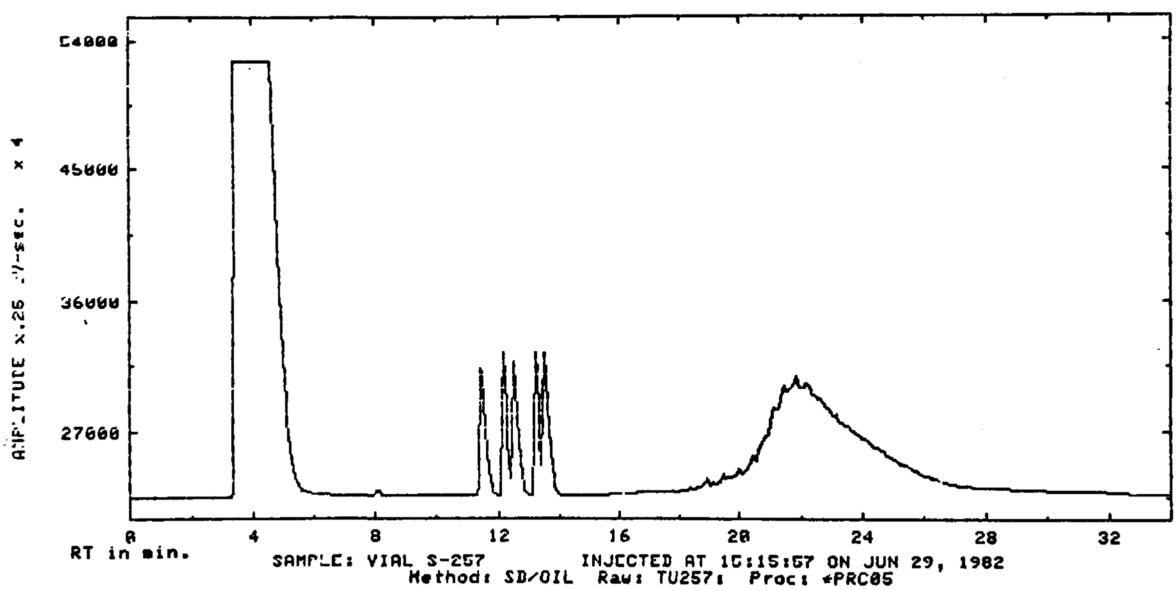

Figure C-3. Boiling Point Distribution of SOF derived from hot-start transient operation with SRC-II Blend

APPENDIX D

TEST RESULTS WITH 5 PERCENT LUBE OIL (EM-517-F)

TABLE D-1. FULL LOAD PERFORMANCE DATA FROM THE MACK EM6-300 WITH (EM-517-F) 5 PERCENT LUBE OIL BLEND

Engine Speed	rpm	2100	1900	1700	1500	1260	1000
Torque	ft-lb	783	880	967	1032	1113	1077
	(N·m)	(1062)	(1193)	(1311)	(1399)	(1509)	(1460)
Power	hp	313	318	313	295	267	205
	(kW)	(234)	(237)	(234)	(220)	(199)	(153)
Fuel Rate	lb/hr	117.8	112.6	107.4	99.4	91.4	77.1
Fuel Temp.[a]	°F	100	103	104	104	104	105
Fuel Press.[b]	psig	20.0	22.6	19.0	17.8	16.8	16.0
Inlet Air Rate	lb/min	56.1	53.2	47.4	39.6	32.1	22.1
Inlet Air Depress.[c]	in H_2O	36.0	30.5	24.8	18.0	12.3	7.0
Inlet Air Temp.[d]	°F	73	72	73	73	74	75
Turbo Boost Press.	psig	22.6	19.5	21.0	18.8	16.9	13.0
Manifold Inlet Temp.	°F	120	122	122	122	121	114
Exhaust Back. Press.[e]	in Hg	2.5	2.2	1.7	1.2	0.8	0.4
Exhaust Temp.[e]	°F	852	854	897	964	1059	1158
Coolant Water Out	°F	190	197	196	196	198	200

Note: These data taken during run for power curve smoke - mode was held only long enough to record necessary data (approximately 2 minutes)

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[a] Monitored at connection to injection pump
[b] Monitored after fuel filter
[c] Indicated reading using 4 inch tube metering section per 312GS148
[d] Monitored upstream of metering section
[e] Indicated reading using 5 inch tube metering section per 312GS148

TABLE D-2. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 5 PCT LUBE OIL BLEND BAROMETER: 28.91
TEST-04-01 FUEL:EM-517-F PROJECT: 05-5830-014 DATE:6/02/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.017	3.34	64.	.998	290.	269.	1.12	285.	26.	48.	83.	1
2	2	INTER / 1260.	30.	3.9	.061	6.83	64.	.997	300.	278.	1.66	360.	65.	120.	254.	2
3	25	INTER / 1260.	377.	49.8	.190	7.55	64.	.992	254.	161.	5.30	1035.	57.	70.	726.	3
4	50	INTER / 1260.	753.	99.3	.349	8.93	64.	.984	252.	217.	8.11	1800.	70.	113.	1505.	4
5	75	INTER / 1260.	1130.	149.1	.531	11.83	64.	.981	204.	852.	9.44	1650.	74.	577.	1788.	5
6	100	INTER / 1260.	1519.	200.4	.707	14.42	64.	.979	78.	1423.	10.34	1575.	35.	1167.	2065.	6
7		IDLE / 650.	0.	.0	.016	3.20	64.	.980	280.	260.	1.08	295.	24.	44.	80.	7
8	100	RATED / 2100.	1058.	232.7	.908	25.82	64.	.986	182.	153.	7.18	690.	147.	234.	1699.	8
9	75	RATED / 2100.	785.	172.7	.685	22.12	64.	.987	248.	108.	6.32	615.	170.	141.	1298.	9
10	50	RATED / 2100.	524.	115.1	.494	18.69	64.	.989	288.	123.	5.61	485.	159.	131.	831.	10
11	25	RATED / 2100.	262.	57.6	.298	14.73	64.	.989	292.	177.	4.31	340.	125.	147.	456.	11
12	2	RATED / 2100.	20.	4.5	.144	11.74	64.	.992	370.	201.	2.40	215.	133.	143.	247.	12
13		IDLE / 650.	0.	.0	.017	3.23	64.	.980	356.	278.	1.12	280.	32.	50.	80.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	GRAMS/KG-FUEL CO	GRAMS/KG-FUEL NOX	GRAMS/KW-HR HC	GRAMS/KW-HR CO	GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	24.99	46.36	79.99	******	******	******	.0053	.0691	.076	.987	.0056	6.2	.996	*****	.067	1
2	17.77	32.79	69.06	16.58	30.60	64.43	.0090	.0691	.131	.983	.0081	-10.0	1.003	.931	.080	2
3	5.00	6.11	63.54	1.15	1.40	14.60	.0255	.0691	.369	.952	.0249	-2.2	1.003	.229	.080	3
4	3.32	5.39	71.81	.70	1.14	15.15	.0395	.0691	.571	.930	.0376	-4.8	1.006	.210	.080	4
5	2.33	18.09	56.07	.50	3.87	11.99	.0453	.0691	.656	.919	.0437	-3.5	1.016	.210	.080	5
6	.82	27.50	48.64	.17	5.82	10.30	.0495	.0691	.717	.912	.0479	-3.4	1.028	.206	.080	6
7	25.01	46.46	84.29	******	******	******	.0050	.0691	.072	.987	.0054	7.6	1.002	*****	.067	7
8	2.69	4.30	31.20	.63	1.01	7.30	.0355	.0691	.514	.937	.0333	-6.0	1.092	.214	.080	8
9	4.13	3.44	31.58	.98	.82	7.51	.0312	.0691	.452	.944	.0295	-5.6	1.067	.223	.080	9
10	5.37	4.41	28.07	1.38	1.13	7.22	.0267	.0691	.386	.949	.0263	-1.3	1.045	.246	.080	10
11	6.98	8.23	25.52	2.17	2.56	7.92	.0204	.0691	.295	.960	.0204	-.0	1.028	.302	.080	11
12	15.42	16.58	28.69	29.71	31.92	55.25	.0123	.0691	.179	.976	.0116	-6.0	1.019	1.891	.080	12
13	30.48	47.60	76.68	******	******	******	.0054	.0691	.079	.987	.0056	3.4	1.003	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- = 1.016 GRAM/KW-HR (.758 GRAM/BHP-HR)
BSCO ------- = 2.730 GRAM/KW-HR (2.037 GRAM/BHP-HR (
BSNOX ------ = 10.204 GRAM/KW-HR (7.612 GRAM/BHP-HR)
BSHC + BSNOX = 11.220 GRAM/KW-HR (8.370 GRAM/BHP-HR)
CORR. BSFC - = .233 KG/KW-HR (.384 LBS/BHP-HR)

TABLE D-3. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 5 PERCENT LUBE OIL BLEND BAROMETER: 28.95
TEST-04-02 FUEL: EM-517-F PROJECT: 05-5830-014 DATE: 06/03/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.021	3.29	91.	1.070	320.	276.	1.17	285.	34.	58.	104.	1
2	2	INTER / 1260.	30.	3.9	.060	6.70	91.	1.072	316.	287.	1.75	395.	64.	115.	277.	2
3	25	INTER / 1260.	377.	49.8	.190	7.65	91.	1.056	284.	169.	5.30	1035.	64.	73.	773.	3
4	50	INTER / 1260.	753.	99.3	.346	9.06	91.	1.037	274.	201.	8.02	1785.	76.	105.	1576.	4
5	75	INTER / 1260.	1130.	149.1	.512	11.62	91.	1.031	194.	792.	9.33	1635.	69.	523.	1818.	5
6	100	INTER / 1260.	1519.	200.4	.691	14.43	91.	1.026	78.	1354.	10.11	1530.	35.	1110.	2100.	6
7		IDLE / 650.	0.	.0	.018	3.20	91.	1.061	272.	243.	1.17	320.	25.	44.	100.	7
8	100	RATED / 2100.	1044.	229.7	.884	25.68	91.	1.046	172.	153.	7.09	665.	137.	231.	1714.	8
9	75	RATED / 2100.	785.	172.7	.676	22.72	91.	1.046	264.	116.	6.41	600.	176.	148.	1304.	9
10	50	RATED / 2100.	524.	115.1	.495	18.98	91.	1.049	306.	130.	5.61	465.	170.	138.	848.	10
11	25	RATED / 2100.	262.	57.6	.311	15.14	91.	1.052	318.	169.	4.45	300.	138.	142.	432.	11
12	2	RATED / 2100.	20.	4.5	.142	11.98	91.	1.051	400.	201.	2.51	200.	136.	135.	231.	12
13		IDLE / 650.	0.	.0	.019	3.21	91.	1.061	460.	287.	1.04	240.	47.	59.	86.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	GRAMS/KG-FUEL CO	GRAMS/KG-FUEL NOX	GRAMS/KW-HR HC	GRAMS/KW-HR CO	GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	26.40	45.48	82.02	************		******	.0065	.0691	.094	.986	.0058	-10.3	1.003	*****	.067	1
2	17.80	32.13	77.37	16.20	29.23	70.40	.0090	.0691	.131	.980	.0086	-5.0	1.007	.903	.080	2
3	5.59	6.41	67.59	1.28	1.47	15.53	.0252	.0691	.365	.951	.0249	-1.3	1.008	.228	.080	3
4	3.66	5.05	75.85	.76	1.06	15.86	.0387	.0691	.560	.929	.0372	-4.0	1.015	.206	.080	4
5	2.24	17.02	59.12	.46	3.51	12.19	.0447	.0691	.647	.919	.0432	-3.3	1.021	.202	.080	5
6	.83	26.77	50.65	.17	5.54	10.47	.0485	.0691	.702	.913	.0468	-3.5	1.030	.201	.080	6
7	22.60	40.31	91.89	************		******	.0057	.0691	.083	.985	.0058	1.1	1.006	*****	.067	7
8	2.58	4.35	32.30	.60	1.01	7.46	.0349	.0691	.505	.936	.0329	-5.6	1.094	.211	.080	8
9	4.35	3.65	32.17	1.02	.86	7.55	.0301	.0691	.436	.942	.0299	-.7	1.078	.218	.080	9
10	5.71	4.66	28.54	1.47	1.20	7.36	.0264	.0691	.383	.948	.0263	-.4	1.054	.245	.080	10
11	7.38	7.61	23.20	2.39	2.46	7.51	.0208	.0691	.301	.957	.0211	1.2	1.037	.312	.080	11
12	15.98	15.85	27.05	30.45	30.20	51.55	.0120	.0691	.174	.974	.0121	.9	1.028	1.853	.080	12
13	41.80	52.16	75.49	************		******	.0060	.0691	.086	.987	.0053	-11.1	1.006	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- =	1.064	GRAM/KW-HR	(.794	GRAM/BHP-HR)
BSCO ------- =	2.638	GRAM/KW-HR	(1.968	GRAM/BHP-HR (
BSNOX ------ =	10.456	GRAM/KW-HR	(7.800	GRAM/BHP-HR)
BSHC + BSNOX =	11.520	GRAM/KW-HR	(8.594	GRAM/BHP-HR)
CORR. BSFC - =	.230	KG/KW-HR	(.378	LBS/BHP-HR)

TABLE D-4. REGULATED EMISSIONS SUMMARY FROM TRANSIENT FTP OPERATION OF THE MACK EM6-300 ENGINE WITH (EM-517-F) 5 PERCENT LUBE OIL BLEND

Cycle Type	Transient Emissions, g/kW-hr (g/hp-hr) HC	CO	NO_x Cont.	NO_x Bag	Part.	Cycle BSFC kg/kW-hr (lb/hp-hr)	Cycle Work kW-hr (hp-hr)
Cold Start	0.97 (0.72)	5.09 (3.79)	11.14 (8.31)	9.30 (6.94)	0.91 (0.68)	0.276 (0.454)	15.73 (21.09)
Hot Start	0.92 (0.69)	4.35 (3.25)	10.93 (8.15)	9.23 (6.88)	0.83 (0.62)	0.263 (0.432)	15.99 (21.44)
Transient Composite	0.93 (0.69)	4.46 (3.32)	10.96 (8.18)	9.24 (6.89)	0.84 (0.63)	0.270 (0.443)	15.95 (21.38)
Cold Start	1.00 (0.74)	4.46 (3.33)	10.59 (7.89)	8.82 (6.57)	0.88 (0.66)	0.271 (0.445)	16.14 (21.64)
Hot Start	1.03 (0.77)	4.07 (3.04)	10.50 (7.83)	8.97 (6.69)	0.81 (0.61)	0.260 (0.427)	16.05 (21.53)
Transient Composite	1.03 (0.77)	4.13 (3.08)	10.51 (7.84)	8.95 (6.68)	0.82 (0.61)	0.262 (0.430)	16.06 (21.53)

TABLE D-5. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) 1-6
CVS NO. 11

TEST NO.D3-25 RUN4
DATE 6/ 2/82
TIME
DYNO NO. 4

DIESEL EM-517-F
BAG CART NO. 1

BAROMETER 736.35 MM HG(28.99 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-42. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 8.9 GM/KG(62.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.8	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.67 (2142.3)	60.71 (2143.6)	60.71 (2143.7)	60.68 (2142.8)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.62)	.05 (1.62)	.05 (1.62)	.05 (1.62)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.4 (10573.)	303.6 (10719.)	308.7 (10902.)	301.4 (10643.)
HC SAMPLE METER/RANGE/PPM	24.4/11/ 24.	25.5/11/ 25.	47.9/11/ 48.	21.6/11/ 22.
HC BCKGRD METER/RANGE/PPM	7.9/ 1/ 8.	8.3/ 1/ 8.	9.0/ 1/ 9.	9.1/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	83.4/13/ 83.	67.0/13/ 65.	39.5/13/ 37.	67.4/13/ 65.
CO BCKGRD METER/RANGE/PPM	3.2/13/ 3.	3.0/13/ 3.	5.8/13/ 5.	6.2/13/ 6.
CO2 SAMPLE METER/RANGE/PCT	26.7/ 3/ .44	34.0/ 3/ .57	68.9/ 3/ 1.24	23.1/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05	3.1/ 3/ .05	3.2/ 3/ .05	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	5.2/14/ 52.	5.8/14/ 58.	14.4/14/ 144.	5.1/14/ 51.
NOX BCKGRD METER/RANGE/PPM	1.3/ 2/ 1.	1.0/ 2/ 1.	.4/ 3/ 1.	.9/ 2/ 1.
DILUTION FACTOR	29.92	23.25	10.72	34.97
HC CONCENTRATION PPM	17.	18.	40.	13.
CO CONCENTRATION PPM	78.	60.	31.	58.
CO2 CONCENTRATION PCT	.39	.52	1.20	.33
NOX CONCENTRATION PPM	50.3	57.2	143.0	49.9
HC MASS GRAMS	2.89	3.07	7.08	2.22
CO MASS GRAMS	27.19	21.36	10.97	20.46
CO2 MASS GRAMS	2145.9	2901.9	6768.3	1813.3
NOX MASS GRAMS	28.82	33.18	84.41	28.76
FUEL KG (LB)	.692 (1.53)	.927 (2.04)	2.144 (4.73)	.583 (1.29)
KW HR (HP HR)	2.10 (2.81)	2.92 (3.91)	8.69 (11.65)	2.03 (2.72)
BSHC G/KW HR (G/HP HR)	1.38 (1.03)	1.05 (.78)	.82 (.61)	1.09 (.82)
BSCO G/KW HR (G/HP HR)	12.98 (9.68)	7.33 (5.46)	1.26 (.94)	10.09 (7.52)
BSCO2 G/KW HR (G/HP HR)	1024.10 (763.67)	995.27 (742.18)	779.09 (580.97)	894.00 (666.66)
BSNOX G/KW HR (G/HP HR)	13.75 (10.26)	11.38 (8.49)	9.72 (7.25)	14.18 (10.57)
BSFC KG/KW HR (LB/HP HR)	.330 (.543)	.318 (.523)	.247 (.406)	.288 (.473)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.73 (21.09)
BSHC G/KW HR (G/HP HR)	.97 (.72)
BSCO G/KW HR (G/HP HR)	5.09 (3.79)
BSCO2 G/KW HR (G/HP HR)	867. (646.)
BSNOX G/KW HR (G/HP HR)	11.14 (8.31)
BSFC KG/KW HR (LB/HP HR)	.276 (.454)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	14.31
	G/KWHR(G/HPHR)	.91 (.68)
	G/KG FUEL (G/LB FUEL)	3.29 (1.49)
	FILTER EFF.	97.8

TABLE D-5 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-25 RUN4
DATE 6/ 2/82
TIME
DYNO NO. 4

DIESEL EM-517-F
BAG CART NO. 1

BAROMETER 736.35 MM HG(28.99 IN HG)
DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)

RELATIVE HUMIDITY , ENGINE-42. PCT , CVS-58. PCT
ABSOLUTE HUMIDITY 8.9 GM/KG(62.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.8	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.67 (2142.3)	60.71 (2143.6)	60.71 (2143.7)	60.68 (2142.8)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.62)	.05 (1.62)	.05 (1.62)	.05 (1.62)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.4 (10573.)	303.6 (10719.)	308.7 (10902.)	301.4 (10643.)
HC SAMPLE METER/RANGE/PPM	24.4/11/ 24.	25.5/11/ 25.	47.9/11/ 48.	21.6/11/ 22.
HC BCKGRD METER/RANGE/PPM	7.9/ 1/ 8.	8.3/ 1/ 8.	9.0/ 1/ 9.	9.1/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	83.4/13/ 83.	67.0/13/ 65.	39.5/13/ 37.	67.4/13/ 65.
CO BCKGRD METER/RANGE/PPM	3.2/13/ 3.	3.0/13/ 3.	5.8/13/ 5.	6.2/13/ 6.
CO2 SAMPLE METER/RANGE/PCT	26.7/ 3/ .44	34.0/ 3/ .57	68.9/ 3/ 1.24	23.1/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05	3.1/ 3/ .05	3.2/ 3/ .05	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	46.4/ 2/ 46.	50.3/ 2/ 50.	38.2/ 3/ 115.	43.8/ 2/ 44.
NOX BCKGRD METER/RANGE/PPM	1.3/ 2/ 1.	1.0/ 2/ 1.	.4/ 3/ 1.	.9/ 2/ 1.
DILUTION FACTOR	29.92	23.25	10.72	34.97
HC CONCENTRATION PPM	17.	18.	40.	13.
CO CONCENTRATION PPM	78.	60.	31.	58.
CO2 CONCENTRATION PCT	.39	.52	1.20	.33
NOX CONCENTRATION PPM	45.1	49.3	113.5	42.9
HC MASS GRAMS	2.89	3.07	7.08	2.22
CO MASS GRAMS	27.19	21.36	10.97	20.46
CO2 MASS GRAMS	2145.9	2901.9	6768.3	1813.3
NOX MASS GRAMS	25.85	28.64	67.02	24.74
FUEL KG (LB)	.692 (1.53)	.927 (2.04)	2.144 (4.73)	.583 (1.29)
KW HR (HP HR)	2.10 (2.81)	2.92 (3.91)	8.69 (11.65)	2.03 (2.72)
BSHC G/KW HR (G/HP HR)	1.38 (1.03)	1.05 (.78)	.82 (.61)	1.09 (.82)
BSCO G/KW HR (G/HP HR)	12.98 (9.68)	7.33 (5.46)	1.26 (.94)	10.09 (7.52)
BSCO2 G/KW HR (G/HP HR)	1024.10 (763.67)	995.27 (742.18)	779.09 (580.97)	894.00 (666.66)
BSNOX G/KW HR (G/HP HR)	12.34 (9.20)	9.82 (7.33)	7.71 (5.75)	12.20 (9.10)
BSFC KG/KW HR (LB/HP HR)	.330 (.543)	.318 (.523)	.247 (.406)	.288 (.473)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.73 (21.09)
BSHC G/KW HR (G/HP HR)	.97 (.72)
BSCO G/KW HR (G/HP HR)	5.09 (3.79)
BSCO2 G/KW HR (G/HP HR)	867. (646.)
BSNOX G/KW HR (G/HP HR)	9.30 (6.94) Bag
BSFC KG/KW HR (LB/HP HR)	.276 (.454)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	14.31
	G/KWHR(G/HPHR)	.91 (.68)
	G/KG FUEL (G/LB FUEL)	3.29 (1.49)
	FILTER EFF.	97.8

TABLE D-6. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D26H RUN4
DATE 6/ 2/82
TIME
DYNO NO. 4

DIESEL EM-517-F
BAG CART NO. 1

BAROMETER 735.84 MM HG(28.97 IN HG)
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)

RELATIVE HUMIDITY , ENGINE-40. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(61.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.8	299.8	304.8	297.7
TOT. BLOWER RATE SCMM (SCFM)	60.64 (2141.1)	60.64 (2141.2)	60.66 (2141.8)	60.64 (2141.2)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.78)	.05 (1.78)	.05 (1.78)	.05 (1.78)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.2 (10564.)	303.3 (10708.)	308.4 (10889.)	301.1 (10633.)
HC SAMPLE METER/RANGE/PPM	19.7/11/ 20.	25.0/11/ 25.	51.6/11/ 52.	21.1/11/ 21.
HC BCKGRD METER/RANGE/PPM	9.7/ 1/ 10.	9.1/ 1/ 9.	8.8/ 1/ 9.	7.8/ 1/ 8.
CO SAMPLE METER/RANGE/PPM	77.5/13/ 76.	64.3/13/ 62.	39.4/13/ 37.	64.3/13/ 62.
CO BCKGRD METER/RANGE/PPM	12.3/13/ 11.	11.0/13/ 10.	8.5/13/ 8.	6.2/13/ 6.
CO2 SAMPLE METER/RANGE/PCT	24.0/ 3/ .39	31.3/ 3/ .52	69.0/ 3/ 1.24	23.4/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	3.0/ 3/ .05	2.8/ 3/ .04	2.9/ 3/ .04	2.9/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	5.0/14/ 50.	5.7/14/ 57.	14.5/14/ 145.	5.2/14/ 52.
NOX BCKGRD METER/RANGE/PPM	.8/ 2/ 1.	.8/ 2/ 1.	.4/ 3/ 1.	1.0/ 2/ 1.
DILUTION FACTOR	33.53	25.41	10.70	34.54
HC CONCENTRATION PPM	10.	16.	44.	14.
CO CONCENTRATION PPM	64.	51.	28.	55.
CO2 CONCENTRATION PCT	.35	.48	1.20	.34
NOX CONCENTRATION PPM	48.9	55.9	144.0	51.3
HC MASS GRAMS	1.77	2.84	7.76	2.36
CO MASS GRAMS	22.21	17.95	10.14	19.30
CO2 MASS GRAMS	1893.6	2652.5	6795.8	1856.7
NOX MASS GRAMS	27.97	32.42	84.90	29.52
FUEL KG (LB)	.609 (1.34)	.847 (1.87)	2.153 (4.75)	.597 (1.32)
KW HR (HP HR)	2.13 (2.85)	2.92 (3.92)	8.86 (11.88)	2.08 (2.79)
BSHC G/KW HR (G/HP HR)	.83 (.62)	.97 (.72)	.88 (.65)	1.13 (.84)
BSCO G/KW HR (G/HP HR)	10.45 (7.79)	6.14 (4.58)	1.14 (.85)	9.28 (6.92)
BSCO2 G/KW HR (G/HP HR)	891.00 (664.42)	907.41 (676.65)	767.11 (572.04)	892.42 (665.48)
BSNOX G/KW HR (G/HP HR)	13.16 (9.81)	11.09 (8.27)	9.58 (7.15)	14.19 (10.58)
BSFC KG/KW HR (LB/HP HR)	.287 (.471)	.290 (.476)	.243 (.399)	.287 (.471)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.99 (21.44)
BSHC G/KW HR (G/HP HR)	.92 (.69)
BSCO G/KW HR (G/HP HR)	4.35 (3.25)
BSCO2 G/KW HR (G/HP HR)	826. (616.)
BSNOX G/KW HR (G/HP HR)	10.93 (8.15)
BSFC KG/KW HR (LB/HP HR)	.263 (.432)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	13.34
G/KWHR(G/HPHR)	.83 (.62)
G/KG FUEL (G/LB FUEL)	3.17 (1.44)
FILTER EFF.	98.1

TABLE D-6 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D26H RUN4
DATE 6/ 2/82
TIME
DYNO NO. 4

DIESEL EM-517-F
BAG CART NO. 1

BAROMETER 735.84 MM HG(28.97 IN HG)
DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)

RELATIVE HUMIDITY , ENGINE-40. PCT , CVS-59. PCT
ABSOLUTE HUMIDITY 8.7 GM/KG(61.1 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.8	299.8	304.8	297.7
TOT. BLOWER RATE SCMM (SCFM)	60.64 (2141.1)	60.64 (2141.2)	60.66 (2141.8)	60.64 (2141.2)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.78)	.05 (1.78)	.05 (1.78)	.05 (1.78)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	299.2 (10564.)	303.3 (10708.)	308.4 (10889.)	301.1 (10633.)
HC SAMPLE METER/RANGE/PPM	19.7/11/ 20.	25.0/11/ 25.	51.6/11/ 52.	21.1/11/ 21.
HC BCKGRD METER/RANGE/PPM	9.7/ 1/ 10.	9.1/ 1/ 9.	8.8/ 1/ 9.	7.8/ 1/ 8.
CO SAMPLE METER/RANGE/PPM	77.5/13/ 76.	64.3/13/ 62.	39.4/13/ 37.	64.3/13/ 62.
CO BCKGRD METER/RANGE/PPM	12.3/13/ 11.	11.0/13/ 10.	8.5/13/ 8.	6.2/13/ 6.
CO2 SAMPLE METER/RANGE/PCT	24.0/ 3/ .39	31.3/ 3/ .52	69.0/ 3/ 1.24	23.4/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	3.0/ 3/ .05	2.8/ 3/ .04	2.9/ 3/ .04	2.9/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	44.4/ 2/ 44.	49.0/ 2/ 49.	39.1/ 3/ 117.	46.2/ 2/ 46.
NOX BCKGRD METER/RANGE/PPM	.8/ 2/ 1.	.8/ 2/ 1.	.4/ 3/ 1.	1.0/ 2/ 1.
DILUTION FACTOR	33.53	25.41	10.70	34.54
HC CONCENTRATION PPM	10.	16.	44.	14.
CO CONCENTRATION PPM	64.	51.	28.	55.
CO2 CONCENTRATION PCT	.35	.48	1.20	.34
NOX CONCENTRATION PPM	43.6	48.2	116.2	45.2
HC MASS GRAMS	1.77	2.84	7.76	2.36
CO MASS GRAMS	22.21	17.95	10.14	19.30
CO2 MASS GRAMS	1893.6	2652.5	6795.8	1856.7
NOX MASS GRAMS	24.96	27.97	68.54	26.05
FUEL KG (LB)	.609 (1.34)	.847 (1.87)	2.153 (4.75)	.597 (1.32)
KW HR (HP HR)	2.13 (2.85)	2.92 (3.92)	8.86 (11.88)	2.08 (2.79)
BSHC G/KW HR (G/HP HR)	.83 (.62)	.97 (.72)	.88 (.65)	1.13 (.84)
BSCO G/KW HR (G/HP HR)	10.45 (7.79)	6.14 (4.58)	1.14 (.85)	9.28 (6.92)
BSCO2 G/KW HR (G/HP HR)	891.00 (664.42)	907.41 (676.65)	767.11 (572.04)	892.42 (665.48)
BSNOX G/KW HR (G/HP HR)	11.74 (8.76)	9.57 (7.14)	7.74 (5.77)	12.52 (9.34)
BSFC KG/KW HR (LB/HP HR)	.287 (.471)	.290 (.476)	.243 (.399)	.287 (.471)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.99 (21.44)
BSHC G/KW HR (G/HP HR)	.92 (.69)
BSCO G/KW HR (G/HP HR)	4.35 (3.25)
BSCO2 G/KW HR (G/HP HR)	826. (616.)
BSNOX G/KW HR (G/HP HR)	9.23 (6.88) Bag
BSFC KG/KW HR (LB/HP HR)	.263 (.432)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	13.34
	G/KWHR (G/HPHR)	.83 (.62)
	G/KG FUEL (G/LB FUEL)	3.17 (1.44)
	FILTER EFF.	98.1

TABLE D-7. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-27 RUN4
DATE 6/ 3/82
TIME
DYNO NO. 4

DIESEL EM-517-F
BAG CART NO. 1

BAROMETER 736.85 MM HG(29.01 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)

RELATIVE HUMIDITY , ENGINE-51. PCT , CVS-70. PCT
ABSOLUTE HUMIDITY 8.5 GM/KG(59.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.79 (2146.5)	60.79 (2146.6)	60.81 (2147.1)	60.80 (2146.9)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.79)	.05 (1.79)	.05 (1.79)	.05 (1.79)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	300.0 (10594.)	304.1 (10738.)	309.3 (10920.)	302.0 (10665.)
HC SAMPLE METER/RANGE/PPM	29.9/11/ 30.	32.8/11/ 33.	55.7/11/ 56.	26.3/11/ 26.
HC BCKGRD METER/RANGE/PPM	13.5/ 1/ 14.	14.5/ 1/ 15.	14.7/ 1/ 15.	13.7/ 1/ 14.
CO SAMPLE METER/RANGE/PPM	73.9/13/ 72.	62.2/13/ 60.	34.2/13/ 32.	58.1/13/ 55.
CO BCKGRD METER/RANGE/PPM	2.1/13/ 2.	2.2/13/ 2.	2.2/13/ 2.	2.6/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	26.2/ 3/ .43	34.9/ 3/ .58	69.3/ 3/ 1.25	22.9/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.1/ 3/ .05	3.5/ 3/ .05	3.0/ 3/ .05	3.2/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	4.9/14/ 49.	5.6/14/ 56.	14.2/14/ 142.	4.9/14/ 49.
NOX BCKGRD METER/RANGE/PPM	1.2/ 2/ 1.	1.0/ 2/ 1.	.3/ 3/ 1.	1.1/ 2/ 1.
DILUTION FACTOR	30.56	22.60	10.65	35.33
HC CONCENTRATION PPM	17.	19.	42.	13.
CO CONCENTRATION PPM	68.	56.	28.	52.
CO2 CONCENTRATION PCT	.38	.53	1.21	.32
NOX CONCENTRATION PPM	47.5	55.2	141.3	48.3
HC MASS GRAMS	2.91	3.33	7.56	2.25
CO MASS GRAMS	23.88	19.80	10.21	18.15
CO2 MASS GRAMS	2101.9	2965.7	6841.7	1789.5
NOX MASS GRAMS	27.26	32.12	83.59	27.87
FUEL KG (LB)	.677 (1.49)	.947 (2.09)	2.167 (4.78)	.575 (1.27)
KW HR (HP HR)	2.10 (2.82)	3.01 (4.04)	8.96 (12.01)	2.07 (2.77)
BSHC G/KW HR (G/HP HR)	1.38 (1.03)	1.11 (.82)	.84 (.63)	1.09 (.81)
BSCO G/KW HR (G/HP HR)	11.36 (8.47)	6.57 (4.90)	1.14 (.85)	8.79 (6.55)
BSCO2 G/KW HR (G/HP HR)	999.56 (745.37)	984.41 (734.07)	763.94 (569.67)	866.35 (646.04)
BSNOX G/KW HR (G/HP HR)	12.96 (9.67)	10.66 (7.95)	9.33 (6.96)	13.49 (10.06)
BSFC KG/KW HR (LB/HP HR)	.322 (.529)	.314 (.517)	.242 (.398)	.278 (.457)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.14 (21.64)
BSHC G/KW HR (G/HP HR)	1.00 (.74)
BSCO G/KW HR (G/HP HR)	4.46 (3.33)
BSCO2 G/KW HR (G/HP HR)	849. (633.)
BSNOX G/KW HR (G/HP HR)	10.59 (7.89)
BSFC KG/KW HR (LB/HP HR)	.271 (.445)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	14.19
	G/KWHR(G/HPHR)	.88 (.66)
	G/KG FUEL (G/LB FUEL)	3.25 (1.47)
	FILTER EFF.	98.1

TABLE D-8 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-28 RUN4
DATE 6/ 3/82
TIME
DYNO NO. 4

DIESEL EM-517-F
BAG CART NO. 1

BAROMETER 736.85 MM HG(29.01 IN HG)
DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)

RELATIVE HUMIDITY , ENGINE-53. PCT , CVS-70. PCT
ABSOLUTE HUMIDITY 9.8 GM/KG(68.6 GRAINS/LB)
NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	296.0	300.0	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	60.79 (2146.4)	60.77 (2145.8)	60.80 (2146.8)	60.79 (2146.6)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.78)	.05 (1.78)	.05 (1.78)	.05 (1.78)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	300.1 (10598.)	304.1 (10738.)	309.2 (10918.)	302.0 (10663.)
HC SAMPLE METER/RANGE/PPM	24.4/11/ 24.	28.9/11/ 29.	55.1/11/ 55.	24.7/11/ 25.
HC BCKGRD METER/RANGE/PPM	11.2/ 1/ 11.	10.7/ 1/ 11.	9.9/ 1/ 10.	9.4/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	64.7/13/ 62.	53.1/13/ 50.	33.3/13/ 31.	56.6/13/ 54.
CO BCKGRD METER/RANGE/PPM	1.9/13/ 2.	1.5/13/ 1.	1.6/13/ 1.	1.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	24.2/ 3/ .39	31.9/ 3/ .53	67.9/ 3/ 1.22	22.9/ 3/ .37
CO2 BCKGRD METER/RANGE/PCT	3.2/ 3/ .05	3.1/ 3/ .05	2.9/ 3/ .04	2.9/ 3/ .04
NOX SAMPLE METER/RANGE/PPM	44.2/ 2/ 44.	49.5/ 2/ 50.	37.6/ 3/ 113.	45.1/ 2/ 45.
NOX BCKGRD METER/RANGE/PPM	1.0/ 2/ 1.	1.2/ 2/ 1.	.6/ 3/ 2.	1.3/ 2/ 1.
DILUTION FACTOR	33.32	24.93	10.89	35.36
HC CONCENTRATION PPM	14.	19.	46.	16.
CO CONCENTRATION PPM	59.	47.	28.	51.
CO2 CONCENTRATION PCT	.35	.48	1.18	.33
NOX CONCENTRATION PPM	43.2	48.3	111.2	43.8
HC MASS GRAMS	2.35	3.27	8.22	2.71
CO MASS GRAMS	20.59	16.78	10.09	17.92
CO2 MASS GRAMS	1902.2	2695.3	6687.1	1814.1
NOX MASS GRAMS	24.81	28.12	65.74	25.32
FUEL KG (LB)	.612 (1.35)	.860 (1.90)	2.119 (4.67)	.583 (1.28)
KW HR (HP HR)	2.16 (2.90)	2.98 (3.99)	8.81 (11.81)	2.11 (2.83)
BSHC G/KW HR (G/HP HR)	1.09 (.81)	1.10 (.82)	.93 (.70)	1.29 (.96)
BSCO G/KW HR (G/HP HR)	9.52 (7.10)	5.64 (4.21)	1.15 (.85)	8.49 (6.33)
BSCO2 G/KW HR (G/HP HR)	879.63 (655.94)	905.89 (675.52)	759.32 (566.22)	859.63 (641.03)
BSNOX G/KW HR (G/HP HR)	11.47 (8.56)	9.45 (7.05)	7.46 (5.57)	12.00 (8.95)
BSFC KG/KW HR (LB/HP HR)	.283 (.465)	.289 (.475)	.241 (.396)	.276 (.454)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	16.05 (21.53)
BSHC G/KW HR (G/HP HR)	1.03 (.77)
BSCO G/KW HR (G/HP HR)	4.07 (3.04)
BSCO2 G/KW HR (G/HP HR)	816. (608.)
BSNOX G/KW HR (G/HP HR)	8.97 (6.69) Bag
BSFC KG/KW HR (LB/HP HR)	.260 (.427)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	13.03
G/KWHR(G/HPHR)	.81 (.61)
G/KG FUEL (G/LB FUEL)	3.12 (1.42)
FILTER EFF.	98.1

TALBE D-9. TRANSIENT CYCLE STATISTICS AND MODAL EMISSION RATE SUMMARY

TRANSIENT CYCLE STATISTICS

TEST D3-25	Cold Cycle			Hot Cycle		
	Speed	Torque	Power	Speed	Torque	Power
Standard Error	50.0	4.4	5.0	45.5	3.9	4.7
Slope	1.0011	0.9643	0.9937	1.0054	0.9664	1.0031
Corr. Coef.	0.993	0.968	0.975	0.994	0.976	0.979
Intercept	7.9	-5.0	-2.0	9.4	-2.9	-1.7
Points Used	1179	981	981	1179	987	987
Ref. Work (Dev. %)	21.77	(-3.11)		21.77	(-1.54)	

TEST D3-27	Cold Cycle			Hot Cycle		
	Speed	Torque	Power	Speed	Torque	Power
Standard Error	50.2	4.2	4.6	46.1	4.1	4.9
Slope	0.9995	0.9722	1.0066	0.9988	0.9645	0.9997
Corr. Coef.	0.993	0.972	0.979	0.994	0.973	0.977
Intercept	8.6	-1.2	-0.8	13.9	-1.2	-1.0
Points Used	1179	985	985	1179	991	991
Ref. Work (Dev. %)	21.77	(-0.60)		21.77	(-1.10)	

Note:
Units are as given in Federal Register Section 86.1341-84.

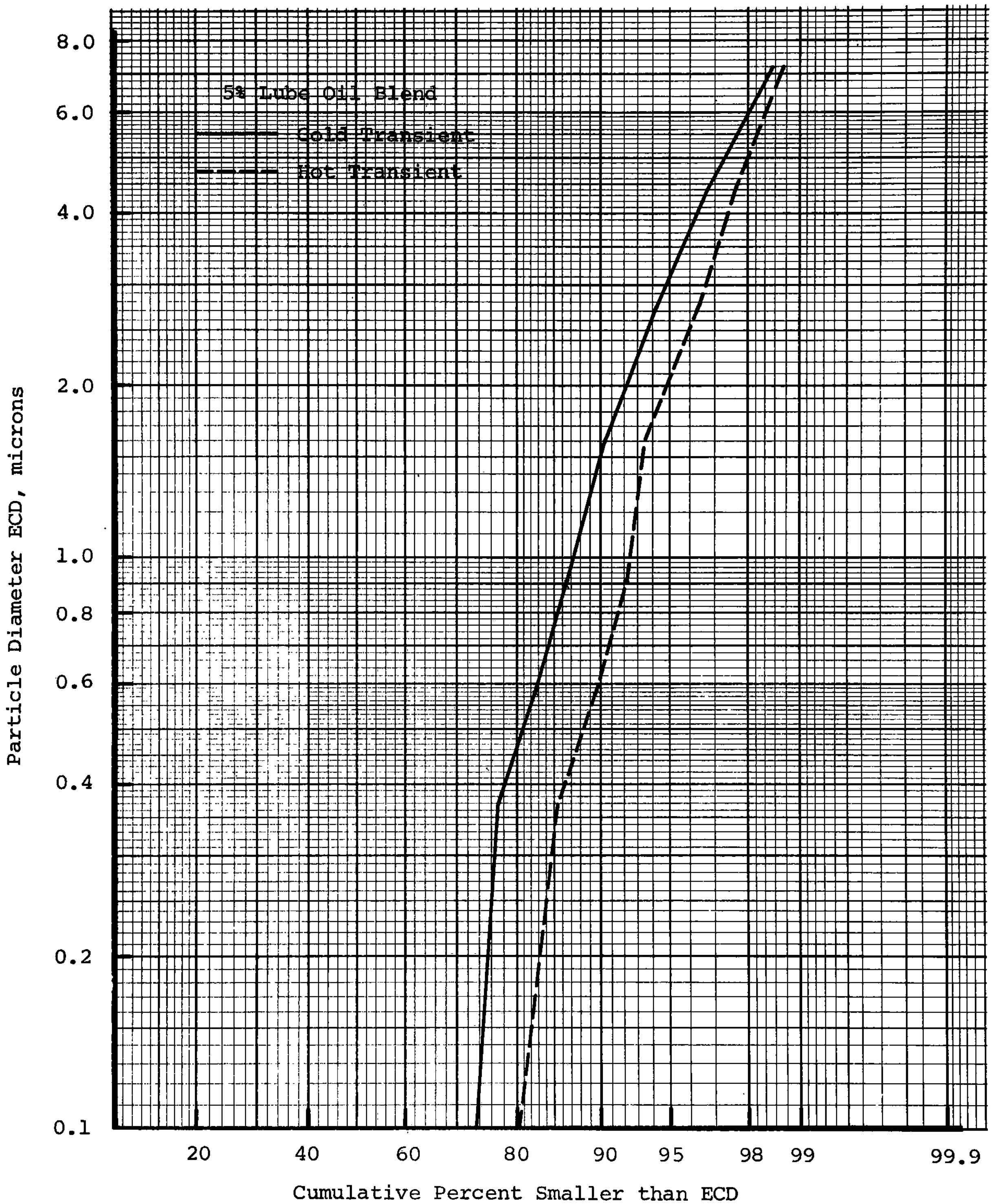

Figure D-1. Particle size distribution from transient operation of the Mack EM6-300 with 5 percent lube oil blend

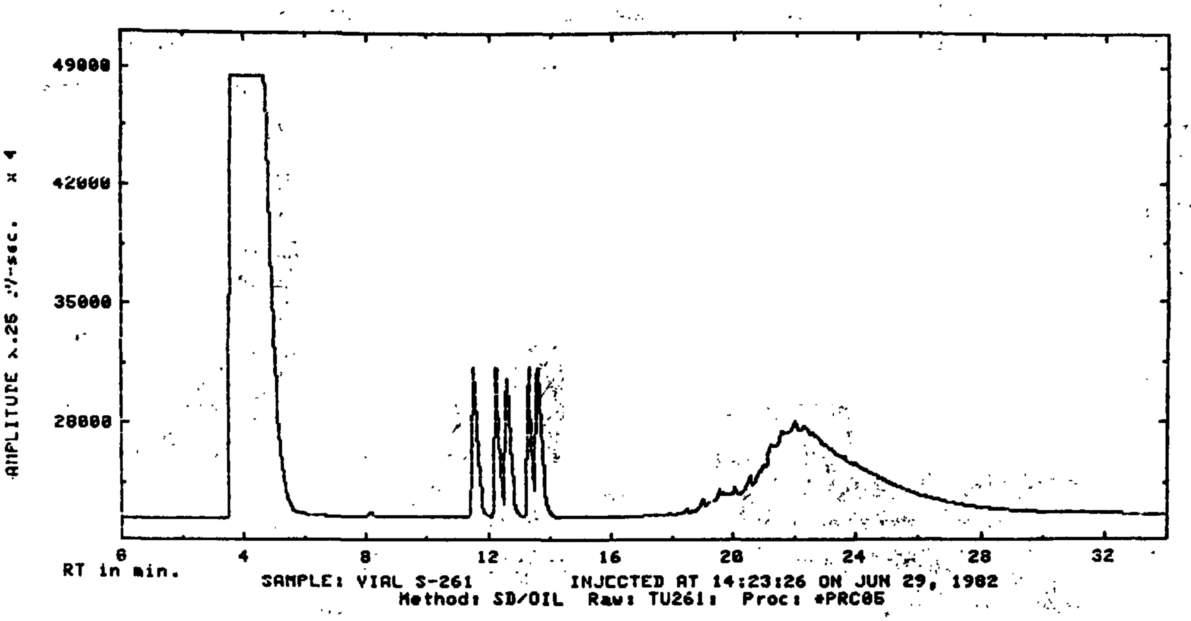

Figure D-2. Boiling Point Distribution of SOF derived from cold-start transient operation with lube oil blend

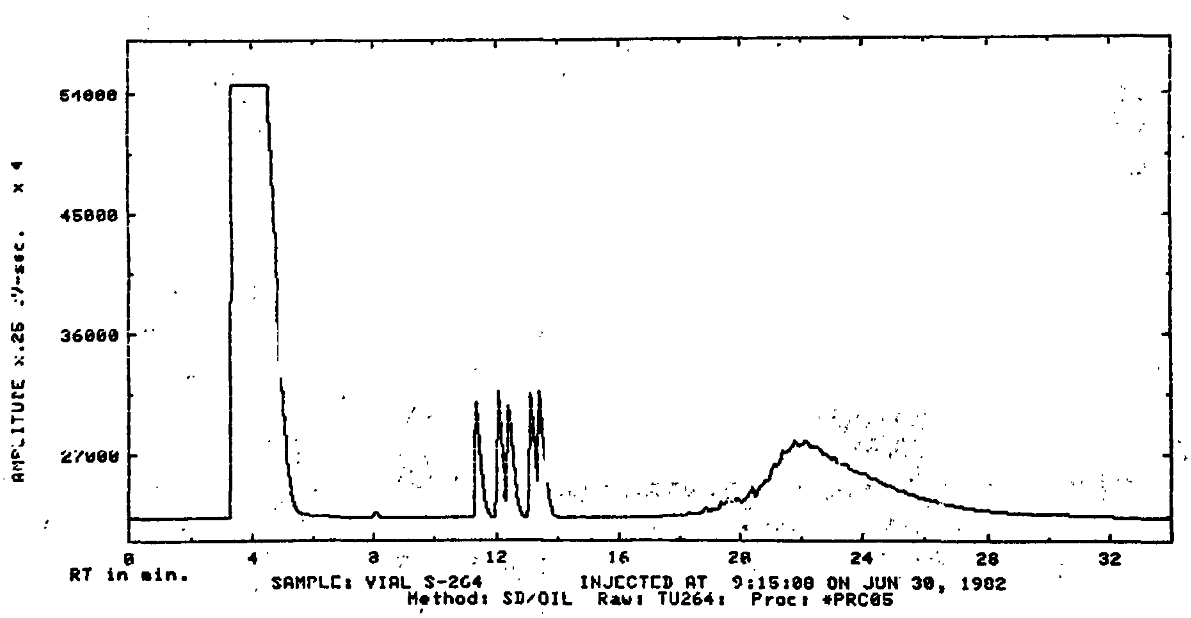

Figure D-3. Boiling Point Distribution of SOF derived from hot-start transient operation with lube oil blend

APPENDIX E

TEST RESULTS WITH NEAT SOYBEAN OIL (EM-510-F)

TABLE E-1. FULL LOAD PERFORMANCE DATA FROM THE MACK EM6-300 WITH (EM-510-F) SOYBEAN OIL @ 145°C (290°F)

Engine Speed	rpm	2100	1900	1700	1500	1260	1000
Torque	ft-lb	612	700	790	860	950	915
	(N·m)	(830)	(949)	(1071)	(1166)	(1288)	(1241)
Power	hp	245	253	256	246	228	174
	(kW)	(183)	(189)	(191)	(184)	(170)	(130)
Fuel Rate	lb/hr	115.8	109.0	105.0	98.2	91.4	74.5
Fuel Temp.[a]	°F	301	297	298	300	301	301
Fuel Press.[b]	psig	--	--	--	--	--	--
Inlet Air Rate	lb/min	52.5	48.0	42.4	36.7	28.3	19.6
Inlet Air Depress.[c]	in H_2O	35.5	28.5	22.5	16.5	12.0	7.0
Inlet Air Temp.[d]	°F	70	71	71	72	72	73
Turbo Boost Press.	psig	19.4	18.6	17.2	15.4	13.8	9.8
Manifold Inlet Temp.	°F	120	122	123	123	123	112
Exhaust Back. Press.[e]	in Hg	2.5	2.1	1.8	1.4	0.8	0.5
Exhaust Temp.[e]	°F	811	815	862	919	999	1086
Coolant Water Out	°F	200	199	200	200	201	203

Note: These data taken during run for power curve smoke - mode was held only long enough to record necessary data (approximately 2 minutes)

[a] Monitored at connection to injection pump
[b] Monitored after fuel filter
[c] Indicated reading using 4 inch tube metering section per 312GS148
[d] Monitored upstream of metering section
[e] Indicated reading using 5 inch tube metering section per 312GS148

TABLE E-2. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 SOYBEAN OIL BAROMETER: 29.00
TEST-05-01 FUEL: EM-510-F PROJECT: 05-5830-014 DATE: 6/15/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 650.	0.	.0	.020	3.25	11.7	1.036	140.	642.	1.04	80.	13.	123.	26.	1
2	2	INTER / 1260.	30.	3.9	.059	6.78	11.7	1.025	208.	567.	1.61	215.	40.	216.	137.	2
3	25	INTER / 1260.	377.	49.8	.230	7.62	11.7	1.023	134.	217.	5.53	735.	31.	98.	552.	3
4	50	INTER / 1260.	753.	99.3	.427	9.12	11.7	1.015	120.	185.	8.41	1260.	35.	102.	1150.	4
5	75	INTER / 1260.	1130.	149.1	.621	11.62	11.7	1.011	136.	642.	9.66	1335.	51.	446.	1531.	5
6	100	INTER / 1260.	1309.	172.7	.713	12.96	11.7	1.010	100.	852.	9.88	1335.	42.	663.	1713.	6
7		IDLE / 650.	0.	.0	.020	3.21	11.7	1.021	116.	591.	1.04	80.	11.	114.	26.	7
8	100	RATED / 2100.	841.	184.9	.882	23.45	11.8	1.031	100.	115.	6.66	555.	76.	165.	1342.	8
9	75	RATED / 2100.	785.	172.7	.779	22.76	11.8	1.039	90.	130.	6.41	555.	62.	171.	1240.	9
10	50	RATED / 2100.	524.	115.1	.583	19.29	11.8	1.045	66.	138.	5.53	430.	39.	158.	839.	10
11	25	RATED / 2100.	262.	57.6	.350	14.93	11.8	1.053	66.	169.	4.31	285.	30.	149.	431.	11
12	2	RATED / 2100.	20.	4.5	.163	12.29	11.8	1.068	112.	251.	2.62	180.	38.	168.	210.	12
13		IDLE / 650.	0.	.0	.020	3.19	11.8	1.064	118.	591.	1.04	95.	11.	114.	32.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	CALCULATED GRAMS/KG-FUEL CO	CALCULATED GRAMS/KG-FUEL NOX	CALCULATED GRAMS/KW-HR HC	CALCULATED GRAMS/KW-HR CO	CALCULATED GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	11.41	*****	21.95	******	******	*****	.0061	.0802	.076	.987	.0059	-2.9	1.000	*****	.067	1
2	11.29	61.00	38.69	10.15	54.80	34.76	.0088	.0802	.110	.982	.0089	1.5	1.009	.890	.080	2
3	2.28	7.08	40.04	.63	1.96	11.09	.0305	.0802	.380	.950	.0289	-5.1	1.008	.275	.080	3
4	1.38	3.98	44.88	.36	1.03	11.58	.0474	.0802	.590	.927	.0434	-8.4	1.013	.255	.080	4
5	1.37	11.97	41.07	.34	2.99	10.27	.0541	.0802	.674	.918	.0498	-8.0	1.021	.245	.080	5
6	.98	15.51	40.05	.24	3.84	9.92	.0556	.0802	.693	.916	.0509	-8.4	1.025	.242	.080	6
7	9.52	96.61	21.79	******	******	*****	.0062	.0802	.077	.987	.0059	-4.8	1.004	*****	.067	7
8	1.43	3.13	25.36	.41	.89	7.26	.0381	.0802	.474	.941	.0346	-9.2	1.090	.263	.080	8
9	1.34	3.67	26.56	.36	.99	7.18	.0346	.0802	.431	.943	.0333	-3.7	1.075	.252	.080	9
10	1.13	4.51	23.99	.34	1.37	7.29	.0306	.0802	.381	.950	.0289	-5.6	1.051	.289	.080	10
11	1.43	7.08	20.52	.52	2.58	7.48	.0237	.0802	.296	.959	.0227	-4.5	1.033	.353	.080	11
12	3.90	17.16	21.45	8.53	37.56	46.96	.0134	.0802	.168	.973	.0140	4.1	1.018	2.151	.080	12
13	9.68	96.59	26.94	******	******	*****	.0062	.0802	.078	.987	.0059	-5.5	.998	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- =	.471	GRAM/KW-HR	(.352	GRAM/BHP-HR)
BSCO ------- =	2.605	GRAM/KW-HR	(1.943	GRAM/BHP-HR)
BSNOX ------ =	9.127	GRAM/KW-HR	(6.809	GRAM/BHP-HR)
BSHC + BSNOX =	9.598	GRAM/KW-HR	(7.160	GRAM/BHP-HR)
CORR. BSFC - =	.276	KG/KW-HR	(.454	LBS/BHP-HR)

TABLE 2 (Cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 SOYBEAN OIL BAROMETER: 29.00
TEST-05-01 FUEL: EM-510-F PROJECT: 05-5830-014 DATE: 6/15/82

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	SOYBEAN PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL
1	.0197	.0000	.0197	.0000	.0176	15.4277	.9867	.0189	.0061	.0061	.0055
2	.0590	.0000	.0590	.0000	.0527	15.4277	.9816	.0189	.0088	.0088	.0079
3	.2298	.0000	.2298	.0000	.2055	15.4277	.9496	.0189	.0305	.0305	.0273
4	.4271	.0000	.4271	.0000	.3820	15.4277	.9273	.0189	.0474	.0474	.0424
5	.6213	.0000	.6213	.0000	.5557	15.4277	.9176	.0189	.0541	.0541	.0484
6	.7128	.0000	.7128	.0000	.6375	15.4277	.9158	.0189	.0556	.0556	.0498
7	.0197	.0000	.0197	.0000	.0176	15.4277	.9867	.0189	.0062	.0062	.0055
8	.8821	.0000	.8821	.0000	.7890	15.4277	.9408	.0190	.0381	.0381	.0340
9	.7785	.0000	.7785	.0000	.6964	15.4277	.9426	.0190	.0346	.0346	.0310
10	.5828	.0000	.5828	.0000	.5213	15.4277	.9497	.0190	.0306	.0306	.0273
11	.3500	.0000	.3500	.0000	.3130	15.4277	.9595	.0190	.0237	.0237	.0212
12	.1633	.0000	.1633	.0000	.1460	15.4277	.9731	.0190	.0134	.0134	.0120
13	.0197	.0000	.0197	.0000	.0176	15.4277	.9868	.0190	.0062	.0062	.0056

TABLE E-3. 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 SOYBEAN OIL BAROMETER: 29.07
TEST-05-02 FUEL: EM-510-F PROJECT: 05-5830-014 DATE: 6/16/82

MODE	POWER PCT	ENGINE SPEED COND / RPM	TORQUE OBS N X M	POWER OBS KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	INTAKE HUMID G/KG	NOX CORR FACT	MEASURED HC PPM	MEASURED CO PPM	MEASURED CO2 PCT	MEASURED NOX PPM	CALCULATED GRAMS / HOUR HC	CALCULATED GRAMS / HOUR CO	CALCULATED GRAMS / HOUR NOX	MODE
1		IDLE / 636.	0.	.0	.019	3.22	10.8	1.040	112.	591.	1.04	90.	10.	110.	28.	1
2	2	INTER / 1260.	30.	3.9	.060	6.96	10.8	1.052	194.	567.	1.61	220.	38.	221.	147.	2
3	25	INTER / 1260.	377.	49.8	.231	7.75	10.8	1.023	120.	234.	5.30	765.	29.	111.	603.	3
4	50	INTER / 1260.	753.	99.3	.413	8.87	11.2	1.011	102.	342.	8.41	1365.	29.	182.	1198.	4
5	75	INTER / 1260.	1130.	149.1	.607	11.59	11.2	1.004	92.	681.	9.77	1455.	33.	457.	1601.	5
6	100	INTER / 1260.	1288.	170.0	.687	12.70	11.7	1.009	64.	999.	10.22	1485.	25.	724.	1771.	6
7		IDLE / 635.	0.	.0	.018	3.19	11.7	1.041	106.	567.	1.08	110.	9.	98.	32.	7
8	100	RATED / 2100.	841.	184.9	.873	23.42	11.7	1.031	86.	116.	6.58	560.	65.	167.	1358.	8
9	75	RATED / 2100.	785.	172.7	.796	23.00	11.0	1.019	82.	123.	6.24	555.	60.	170.	1277.	9
10	50	RATED / 2100.	524.	115.1	.571	19.25	11.0	1.026	52.	116.	6.08	440.	28.	118.	751.	10
11	25	RATED / 2100.	262.	57.6	.343	15.23	11.0	1.027	66.	153.	4.72	290.	27.	121.	383.	11
12	2	RATED / 2100.	20.	4.5	.159	12.23	12.3	1.068	112.	251.	2.67	175.	36.	160.	195.	12
13		IDLE / 635.	0.	.0	.021	3.19	12.3	1.065	112.	555.	1.17	110.	10.	103.	36.	13

MODE	CALCULATED GRAMS/KG-FUEL HC	GRAMS/KG-FUEL CO	GRAMS/KG-FUEL NOX	GRAMS/KW-HR HC	GRAMS/KW-HR CO	GRAMS/KW-HR NOX	F/A DRY MEAS	F/A STOICH	"PHI"	WET HC CORR FACT	F/A CALC	F/A PCT MEAS	POWER CORR FACT	BSFC CORR KG/KW-HR	MODAL WEIGHT FACTOR	MODE
1	9.19	96.64	24.97	******	******	*****	.0059	.0802	.074	.987	.0059	-.7	.991	*****	.067	1
2	10.54	61.05	40.65	9.71	56.26	37.46	.0088	.0802	.109	.982	.0089	1.6	.993	.928	.080	2
3	2.13	7.96	43.45	.59	2.22	12.12	.0302	.0802	.376	.952	.0278	-8.0	.997	.280	.080	3
4	1.17	7.34	48.37	.29	1.83	12.06	.0470	.0802	.586	.927	.0434	-7.7	1.002	.249	.080	4
5	.92	12.56	43.96	.22	3.07	10.74	.0530	.0802	.660	.917	.0503	-5.0	1.010	.242	.080	5
6	.61	17.57	42.97	.15	4.26	10.42	.0547	.0802	.682	.913	.0526	-3.8	1.017	.238	.080	6
7	8.43	89.73	29.56	******	******	*****	.0058	.0802	.072	.986	.0061	5.6	.996	*****	.067	7
8	1.24	3.19	25.92	.35	.90	7.34	.0377	.0802	.470	.942	.0342	-9.4	1.083	.261	.080	8
9	1.25	3.57	26.75	.34	.99	7.40	.0350	.0802	.436	.944	.0325	-7.2	1.076	.257	.080	9
10	.81	3.45	21.93	.24	1.03	6.52	.0300	.0802	.374	.945	.0316	5.5	1.051	.283	.080	10
11	1.31	5.86	18.61	.47	2.10	6.66	.0228	.0802	.284	.956	.0247	8.6	1.025	.349	.080	11
12	3.83	16.84	20.45	8.15	35.84	43.53	.0131	.0802	.164	.972	.0142	8.5	1.015	2.098	.080	12
13	8.27	81.48	28.07	******	******	*****	.0067	.0802	.084	.985	.0066	-2.5	.997	*****	.067	13

CYCLE COMPOSITE USING 13-MODE WEIGHT FACTORS

BSHC ------- = .394 GRAM/KW-HR (.294 GRAM/BHP-HR)
BSCO ------- = 2.674 GRAM/KW-HR (1.995 GRAM/BHP-HR)
BSNOX ------ = 9.300 GRAM/KW-HR (6.938 GRAM/BHP-HR)
BSHC + BSNOX = 9.694 GRAM/KW-HR (7.232 GRAM/BHP-HR)
CORR. BSFC - = .274 KG/KW-HR (.451 LBS/BHP-HR)

TABLE E-3 (Cont'd). 13-MODE FEDERAL DIESEL EMISSION CYCLE 1979

ENGINE: MACK EM6-300 SOYBEAN OIL BAROMETER: 29.07
TEST-05-02 FUEL: EM-510-F PROJECT: 05-5830-014 DATE: 6/16/82

MODE	TOTAL FUEL KG/MIN	DIESEL PART KG/MIN	Soybean PART KG/MIN	WATER PART KG/MIN	EQIV. DIESEL KG/MIN	FUEL MOLE WEIGHT	HC KWET FACTOR	Y WATER INTAKE	F/A RATIO MASS FUEL	F/A RATIO FUEL CARBON	F/A RATIO EQIV. DIESEL
1	.0189	.0000	.0189	.0000	.0169	15.4277	.9869	.0173	.0059	.0059	.0053
2	.0605	.0000	.0605	.0000	.0541	15.4277	.9819	.0173	.0088	.0088	.0079
3	.2313	.0000	.2313	.0000	.2069	15.4277	.9518	.0173	.0302	.0302	.0270
4	.4127	.0000	.4127	.0000	.3691	15.4277	.9273	.0181	.0470	.0470	.0421
5	.6070	.0000	.6070	.0000	.5429	15.4277	.9168	.0181	.0530	.0530	.0474
6	.6871	.0000	.6871	.0000	.6146	15.4277	.9131	.0188	.0547	.0547	.0490
7	.0181	.0000	.0181	.0000	.0162	15.4277	.9860	.0188	.0058	.0058	.0052
8	.8730	.0000	.8730	.0000	.7809	15.4277	.9415	.0188	.0377	.0377	.0337
9	.7959	.0000	.7959	.0000	.7119	15.4277	.9443	.0177	.0350	.0350	.0313
10	.5707	.0000	.5707	.0000	.5104	15.4277	.9451	.0177	.0300	.0300	.0268
11	.3432	.0000	.3432	.0000	.3069	15.4277	.9559	.0177	.0228	.0228	.0204
12	.1587	.0000	.1587	.0000	.1420	15.4277	.9723	.0197	.0131	.0131	.0117
13	.0212	.0000	.0212	.0000	.0189	15.4277	.9854	.0197	.0067	.0067	.0060

TABLE E-4. REGULATED EMISSIONS SUMMARY FROM TRANSIENT FTP OPERATION OF THE MACK EM6-300 ENGINE WITH (EM-510-F) SOYBEAN OIL AT 145°C

Cold Type	Transient Emissions, g/kW-hr (g/hp-hr) HC	CO	NO_x Cont.	NO_x Bag	Part.	Cycle BSFC kg/kW-hr (lb/hp-hr)	Cycle Work kW-hr (hp-hr)
Cold Start	0.55 (0.41)	5.87 (4.38)	8.00 (5.97)	6.76 (5.04)	1.48 (1.11)	0.315 (0.518)	15.35 (20.59)
Hot Start	0.49 (0.37)	3.77 (2.81)	7.85 (5.86)	6.79 (5.06)	0.80 (0.60)	0.298 (0.490)	15.65 (20.99)
Transient Composite	0.50 (0.38)	4.07 (3.03)	7.87 (5.88)	6.79 (5.06)	0.90 (0.67)	0.300 (0.494)	15.61 (20.93)
Cold Start	0.85 (0.63)	5.31 (3.96)	7.43 (5.54)	6.39 (4.77)	1.49 (1.11)	0.319 (0.525)	15.17 (20.34)
Hot Start	0.42 (0.32)	3.79 (2.82)	7.83 (5.84)	6.60 (4.92)	0.98 (0.73)	0.298 (0.489)	15.48 (20.76)
Transient Composite	0.48 (0.36)	4.01 (2.98)	7.77 (5.80)	6.57 (4.90)	1.05 (0.78)	0.301 (0.494)	15.44 (20.70)

TABLE E-5. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-35 RUN
DATE 6/11/82
TIME
DYNO NO. 4

DIESEL EM-510-F
BAG CART NO. 1

BAROMETER 741.93 MM HG(29.21 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-66. PCT , CVS-50. PCT
ABSOLUTE HUMIDITY 13.0 GM/KG(91.2 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.8	299.8	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.21 (2161.4)	61.20 (2160.8)	61.22 (2161.6)	61.20 (2161.1)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.17)	.06 (2.17)	.06 (2.17)	.06 (2.17)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	302.1 (10666.)	306.1 (10808.)	311.4 (10996.)	304.1 (10737.)
HC SAMPLE METER/RANGE/PPM	36.6/11/ 37.	6.6/13/ 27.	2.8/13/ 11.	8.6/11/ 9.
HC BCKGRD METER/RANGE/PPM	9.2/ 1/ 9.	9.2/ 1/ 9.	8.9/ 1/ 9.	8.9/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	49.6/12/ 105.	75.3/13/ 74.	36.6/13/ 34.	59.9/13/ 57.
CO BCKGRD METER/RANGE/PPM	1.4/12/ 3.	2.5/13/ 2.	2.4/13/ 2.	2.7/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	25.5/ 3/ .42	32.6/ 3/ .54	69.3/ 3/ 1.25	23.5/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	3.5/ 3/ .05	2.8/ 3/ .04	3.1/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	9.8/13/ 30.	12.8/13/ 38.	36.5/13/ 110.	12.0/13/ 36.
NOX BCKGRD METER/RANGE/PPM	1.8/ 2/ 2.	1.0/ 2/ 1.	1.1/ 2/ 1.	1.0/ 2/ 1.
DILUTION FACTOR	31.15	24.27	10.68	34.53
HC CONCENTRATION PPM	28.	18.	3.	-0.
CO CONCENTRATION PPM	100.	70.	31.	54.
CO2 CONCENTRATION PCT	.36	.50	1.21	.33
NOX CONCENTRATION PPM	27.8	37.4	108.5	35.0
HC MASS GRAMS	4.82	3.12	.59	-.01
CO MASS GRAMS	35.13	24.89	11.10	19.01
CO2 MASS GRAMS	2015.3	2808.6	6881.2	1842.7
NOX MASS GRAMS	16.04	21.87	64.63	20.36
FUEL KG (LB)	.735 (1.62)	1.008 (2.22)	2.434 (5.37)	.660 (1.46)
KW HR (HP HR)	2.04 (2.74)	2.74 (3.67)	8.54 (11.45)	2.04 (2.73)
BSHC G/KW HR (G/HP HR)	2.36 (1.76)	1.14 (.85)	.07 (.05)	-.01 (-.01)
BSCO G/KW HR (G/HP HR)	17.19 (12.82)	9.09 (6.78)	1.30 (.97)	9.34 (6.96)
BSCO2 G/KW HR (G/HP HR)	986.33 (735.51)	1026.25 (765.27)	805.92 (600.98)	905.19 (675.00)
BSNOX G/KW HR (G/HP HR)	7.85 (5.85)	7.99 (5.96)	7.57 (5.64)	10.00 (7.46)
BSFC KG/KW HR (LB/HP HR)	.360 (.591)	.368 (.605)	.285 (.469)	.324 (.533)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.35 (20.59)
BSHC G/KW HR (G/HP HR)	.55 (.41)
BSCO G/KW HR (G/HP HR)	5.87 (4.38)
BSCO2 G/KW HR (G/HP HR)	882. (658.)
BSNOX G/KW HR (G/HP HR)	8.00 (5.97)
BSFC KG/KW HR (LB/HP HR)	.315 (.518)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	22.76
G/KWHR(G/HPHR)	1.48 (1.11)
G/KG FUEL (G/LB FUEL)	4.71 (2.13)
FILTER EFF.	96.3

TABLE E-5 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-35 RUN
DATE 6/11/82
TIME
DYNO NO. 4

DIESEL EM-510-F
BAG CART NO. 1

BAROMETER 741.93 MM HG(29.21 IN HG)
DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)

RELATIVE HUMIDITY , ENGINE-66. PCT , CVS-50. PCT
ABSOLUTE HUMIDITY 13.0 GM/KG(91.2 GRAINS/LB)
NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.8	299.8	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.21 (2161.4)	61.20 (2160.8)	61.22 (2161.6)	61.20 (2161.1)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.17)	.06 (2.17)	.06 (2.17)	.06 (2.17)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	302.1 (10666.)	306.1 (10808.)	311.4 (10996.)	304.1 (10737.)
HC SAMPLE METER/RANGE/PPM	36.6/11/ 37.	6.6/13/ 27.	2.8/13/ 11.	8.6/11/ 9.
HC BCKGRD METER/RANGE/PPM	9.2/ 1/ 9.	9.2/ 1/ 9.	8.9/ 1/ 9.	8.9/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	49.6/12/ 105.	75.3/13/ 74.	36.6/13/ 34.	59.9/13/ 57.
CO BCKGRD METER/RANGE/PPM	1.4/12/ 3.	2.5/13/ 2.	2.4/13/ 2.	2.7/13/ 2.
CO2 SAMPLE METER/RANGE/PCT	25.5/ 3/ .42	32.6/ 3/ .54	69.3/ 3/ 1.25	23.5/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	3.5/ 3/ .05	2.8/ 3/ .04	3.1/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	26.7/ 2/ 27.	34.4/ 2/ 34.	89.0/ 2/ 89.	30.9/ 2/ 31.
NOX BCKGRD METER/RANGE/PPM	1.8/ 2/ 2.	1.0/ 2/ 1.	1.1/ 2/ 1.	1.0/ 2/ 1.
DILUTION FACTOR	31.15	24.27	10.68	34.53
HC CONCENTRATION PPM	28.	18.	3.	-0.
CO CONCENTRATION PPM	100.	70.	31.	54.
CO2 CONCENTRATION PCT	.36	.50	1.21	.33
NOX CONCENTRATION PPM	25.0	33.4	88.0	29.9
HC MASS GRAMS	4.82	3.12	.59	-.01
CO MASS GRAMS	35.13	24.89	11.10	19.01
CO2 MASS GRAMS	2015.3	2808.6	6881.2	1842.7
NOX MASS GRAMS	14.42	19.57	52.41	17.40
FUEL KG (LB)	.735 (1.62)	1.008 (2.22)	2.434 (5.37)	.660 (1.46)
KW HR (HP HR)	2.04 (2.74)	2.74 (3.67)	8.54 (11.45)	2.04 (2.73)
BSHC G/KW HR (G/HP HR)	2.36 (1.76)	1.14 (.85)	.07 (.05)	-.01 (-.01)
BSCO G/KW HR (G/HP HR)	17.19 (12.82)	9.09 (6.78)	1.30 (.97)	9.34 (6.96)
BSCO2 G/KW HR (G/HP HR)	986.33 (735.51)	1026.25 (765.27)	805.92 (600.98)	905.19 (675.00)
BSNOX G/KW HR (G/HP HR)	7.06 (5.26)	7.15 (5.33)	6.14 (4.58)	8.55 (6.38)
BSFC KG/KW HR (LB/HP HR)	.360 (.591)	.368 (.605)	.285 (.469)	.324 (.533)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.35 (20.59)
BSHC G/KW HR (G/HP HR)	.55 (.41)
BSCO G/KW HR (G/HP HR)	5.87 (4.38)
BSCO2 G/KW HR (G/HP HR)	882. (658.)
BSNOX G/KW HR (G/HP HR)	6.76 (5.04) Bag
BSFC. KG/KW HR (LB/HP HR)	.315 (.518)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	22.76
	G/KWHR(G/HPHR)	1.48 (1.11)
	G/KG FUEL (G/LB FUEL)	4.71 (2.13)
	FILTER EFF.	96.3

TABLE E-6. ENGINE EMISSION RESULTS
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-36 RUN5
DATE 6/14/82
TIME
DYNO NO. 4

DIESEL EM-510-F
BAG CART NO. 1

BAROMETER 741.68 MM HG(29.20 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)

RELATIVE HUMIDITY , ENGINE-51. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 8.4 GM/KG(58.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.01 (2154.4)	61.02 (2154.5)	61.04 (2155.4)	61.05 (2155.6)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.22)	.06 (2.22)	.06 (2.22)	.06 (2.22)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.2 (10635.)	305.3 (10780.)	310.5 (10964.)	303.3 (10710.)
HC SAMPLE METER/RANGE/PPM	36.4/11/ 36.	28.3/11/ 28.	22.5/11/ 22.	15.5/11/ 16.
HC BCKGRD METER/RANGE/PPM	7.1/ 1/ 7.	7.2/ 1/ 7.	8.0/ 1/ 8.	8.8/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	88.8/13/ 89.	66.7/13/ 65.	35.2/13/ 33.	53.9/13/ 51.
CO BCKGRD METER/RANGE/PPM	.8/13/ 1.	.4/13/ 0.	1.0/13/ 1.	1.3/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	25.6/ 3/ .42	33.2/ 3/ .55	69.7/ 3/ 1.26	23.5/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	3.6/ 3/ .06	3.4/ 3/ .05	3.2/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	23.6/ 2/ 24.	31.9/ 2/ 32.	83.0/ 2/ 83.	29.2/ 2/ 29.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.	.6/ 2/ 1.	.7/ 2/ 1.	.7/ 2/ 1.
DILUTION FACTOR	31.14	23.84	10.61	34.53
HC CONCENTRATION PPM	29.	21.	15.	7.
CO CONCENTRATION PPM	86.	62.	30.	49.
CO2 CONCENTRATION PCT	.36	.50	1.21	.33
NOX CONCENTRATION PPM	22.9	31.3	82.4	28.5
HC MASS GRAMS	5.12	3.76	2.73	1.22
CO MASS GRAMS	30.16	22.15	10.97	17.19
CO2 MASS GRAMS	2010.8	2812.4	6899.9	1838.1
NOX MASS GRAMS	13.20	18.29	48.91	16.54
FUEL KG (LB)	.731 (1.61)	1.008 (2.22)	2.442 (5.38)	.659 (1.45)
KW HR (HP HR)	1.95 (2.61)	2.72 (3.65)	8.46 (11.35)	2.04 (2.73)
BSHC G/KW HR (G/HP HR)	2.63 (1.96)	1.38 (1.03)	.32 (.24)	.60 (.45)
BSCO G/KW HR (G/HP HR)	15.50 (11.56)	8.14 (6.07)	1.30 (.97)	8.44 (6.30)
BSCO2 G/KW HR (G/HP HR)	1033.15 (770.42)	1033.29 (770.53)	815.23 (607.92)	902.89 (673.28)
BSNOX G/KW HR (G/HP HR)	6.78 (5.06)	6.72 (5.01)	5.78 (4.31)	8.13 (6.06)
BSFC KG/KW HR (LB/HP HR)	.376 (.618)	.370 (.609)	.289 (.474)	.324 (.532)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.17 (20.34)
BSHC G/KW HR (G/HP HR)	.85 (.63)
BSCO G/KW HR (G/HP HR)	5.31 (3.96)
BSCO2 G/KW HR (G/HP HR)	894. (667.)
BSNOX G/KW HR (G/HP HR)	6.39 (4.77)
BSFC KG/KW HR (LB/HP HR)	.319 (.525)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	22.57
	G/KWHR(G/HPHR)	1.49 (1.11)
	G/KG FUEL (G/LB FUEL)	4.66 (2.11)
	FILTER EFF.	98.7

TABLE E-6 (Cont'd). ENGINE EMISSION RESULTS -BAG NOx
C-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-36 RUN5
DATE 6/14/82
TIME
DYNO NO. 4

DIESEL EM-510-F
BAG CART NO. 1

BAROMETER 741.68 MM HG(29.20 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)

RELATIVE HUMIDITY , ENGINE-51. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 8.4 GM/KG(58.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.01 (2154.4)	61.02 (2154.5)	61.04 (2155.4)	61.05 (2155.6)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.22)	.06 (2.22)	.06 (2.22)	.06 (2.22)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.2 (10635.)	305.3 (10780.)	310.5 (10964.)	303.3 (10710.)
HC SAMPLE METER/RANGE/PPM	36.4/11/ 36.	28.3/11/ 28.	22.5/11/ 22.	15.5/11/ 16.
HC BCKGRD METER/RANGE/PPM	7.1/ 1/ 7.	7.2/ 1/ 7.	8.0/ 1/ 8.	8.8/ 1/ 9.
CO SAMPLE METER/RANGE/PPM	88.8/13/ 89.	66.7/13/ 65.	35.2/13/ 33.	53.9/13/ 51.
CO BCKGRD METER/RANGE/PPM	.8/13/ 1.	.4/13/ 0.	1.0/13/ 1.	1.3/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	25.6/ 3/ .42	33.2/ 3/ .55	69.7/ 3/ 1.26	23.5/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	3.6/ 3/ .06	3.4/ 3/ .05	3.2/ 3/ .05	3.4/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	8.8/13/ 26.	11.6/13/ 35.	33.4/13/ 100.	11.0/13/ 33.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.	.6/ 2/ 1.	.7/ 2/ 1.	.7/ 2/ 1.
DILUTION FACTOR	31.14	23.84	10.61	34.53
HC CONCENTRATION PPM	29.	21.	15.	7.
CO CONCENTRATION PPM	86.	62.	30.	49.
CO2 CONCENTRATION PCT	.36	.50	1.21	.33
NOX CONCENTRATION PPM	25.6	34.3	99.7	32.4
HC MASS GRAMS	5.12	3.76	2.73	1.22
CO MASS GRAMS	30.16	22.15	10.97	17.19
CO2 MASS GRAMS	2010.8	2812.4	6899.9	1838.1
NOX MASS GRAMS	14.75	20.02	59.19	18.79
FUEL KG (LB)	.731 (1.61)	1.008 (2.22)	2.442 (5.38)	.659 (1.45)
KW HR (HP HR)	1.95 (2.61)	2.72 (3.65)	8.46 (11.35)	2.04 (2.73)
BSHC G/KW HR (G/HP HR)	2.63 (1.96)	1.38 (1.03)	.32 (.24)	.60 (.45)
BSCO G/KW HR (G/HP HR)	15.50 (11.56)	8.14 (6.07)	1.30 (.97)	8.44 (6.30)
BSCO2 G/KW HR (G/HP HR)	1033.15 (770.42)	1033.29 (770.53)	815.23 (607.92)	902.89 (673.28)
BSNOX G/KW HR (G/HP HR)	7.58 (5.65)	7.35 (5.48)	6.99 (5.22)	9.23 (6.88)
BSFC KG/KW HR (LB/HP HR)	.376 (.618)	.370 (.609)	.289 (.474)	.324 (.532)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.17 (20.34)
BSHC G/KW HR (G/HP HR)	.85 (.63)
BSCO G/KW HR (G/HP HR)	5.31 (3.96)
BSCO2 G/KW HR (G/HP HR)	894. (667.)
BSNOX G/KW HR (G/HP HR)	7.43 (5.54) Bag
BSFC KG/KW HR (LB/HP HR)	.319 (.525)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES		
	GRAMS/TEST	22.57
	G/KWHR(G/HPHR)	1.49 (1.11)
	G/KG FUEL (G/LB FUEL)	4.66 (2.11)
	FILTER EFF.	98.7

TABLE E-7. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-37 RUN5
DATE 6/14/82
TIME
DYNO NO. 4

DIESEL EM-510-F
BAG CART NO. 1

BAROMETER 741.43 MM HG(29.19 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)

RELATIVE HUMIDITY , ENGINE-51. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 8.4 GM/KG(58.6 GRAINS/LB)
NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.02 (2154.7)	60.99 (2153.7)	61.05 (2155.7)	61.02 (2154.8)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.69)	.05 (1.69)	.05 (1.69)	.05 (1.69)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.2 (10634.)	305.1 (10773.)	310.5 (10963.)	303.1 (10703.)
HC SAMPLE METER/RANGE/PPM	20.5/11/ 21.	16.1/11/ 16.	19.0/11/ 19.	11.5/11/ 11.
HC BCKGRD METER/RANGE/PPM	8.2/ 1/ 8.	8.0/ 1/ 8.	7.8/ 1/ 8.	7.3/ 1/ 7.
CO SAMPLE METER/RANGE/PPM	63.2/13/ 61.	40.7/13/ 38.	30.5/13/ 28.	48.2/13/ 45.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.3/13/ 0.	.2/13/ 0.	.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	23.3/ 3/ .38	30.8/ 3/ .51	67.6/ 3/ 1.22	23.3/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	3.0/ 3/ .05	2.9/ 3/ .04	3.1/ 3/ .05	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	10.9/13/ 33.	13.0/13/ 39.	34.2/13/ 103.	11.8/13/ 35.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.	.7/ 2/ 1.	.9/ 2/ 1.	1.0/ 2/ 1.
DILUTION FACTOR	34.71	26.01	10.98	34.92
HC CONCENTRATION PPM	13.	8.	12.	4.
CO CONCENTRATION PPM	59.	37.	27.	44.
CO2 CONCENTRATION PCT	.33	.47	1.17	.33
NOX CONCENTRATION PPM	32.2	38.2	101.9	34.3
HC MASS GRAMS	2.18	1.48	2.13	.76
CO MASS GRAMS	20.59	12.98	9.65	15.40
CO2 MASS GRAMS	1839.2	2610.2	6663.9	1842.7
NOX MASS GRAMS	18.53	22.30	60.51	19.87
FUEL KG (LB)	.662 (1.46)	.929 (2.05)	2.358 (5.20)	.659 (1.45)
KW HR (HP HR)	2.13 (2.86)	2.79 (3.74)	8.50 (11.40)	2.06 (2.76)
BSHC G/KW HR (G/HP HR)	1.02 (.76)	.53 (.39)	.25 (.19)	.37 (.28)
BSCO G/KW HR (G/HP HR)	9.65 (7.20)	4.65 (3.47)	1.14 (.85)	7.48 (5.58)
BSCO2 G/KW HR (G/HP HR)	862.36 (643.06)	935.91 (697.91)	783.90 (584.55)	895.32 (667.64)
BSNOX G/KW HR (G/HP HR)	8.69 (6.48)	8.00 (5.96)	7.12 (5.31)	9.65 (7.20)
BSFC KG/KW HR (LB/HP HR)	.311 (.511)	.333 (.548)	.277 (.456)	.320 (.527)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.48 (20.76)
BSHC G/KW HR (G/HP HR)	.42 (.32)
BSCO G/KW HR (G/HP HR)	3.79 (2.82)
BSCO2 G/KW HR (G/HP HR)	837. (624.)
BSNOX G/KW HR (G/HP HR)	7.83 (5.84)
BSFC KG/KW HR (LB/HP HR)	.298 (.489)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	15.13
	G/KWHR(G/HPHR)	.98 (.73)
	G/KG FUEL (G/LB FUEL)	3.28 (1.49)
	FILTER EFF.	97.0

TABLE E-7 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-37 RUN5
DATE 6/14/82
TIME
DYNO NO. 4

DIESEL EM-510-F
BAG CART NO. 1

BAROMETER 741.43 MM HG(29.19 IN HG)
DRY BULB TEMP. 21.7 DEG C(71.0 DEG F)

RELATIVE HUMIDITY , ENGINE-51. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 8.4 GM/KG(58.6 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.02 (2154.7)	60.99 (2153.7)	61.05 (2155.7)	61.02 (2154.8)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.69)	.05 (1.69)	.05 (1.69)	.05 (1.69)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	301.2 (10634.)	305.1 (10773.)	310.5 (10963.)	303.1 (10703.)
HC SAMPLE METER/RANGE/PPM	20.5/11/ 21.	16.1/11/ 16.	19.0/11/ 19.	11.5/11/ 11.
HC BCKGRD METER/RANGE/PPM	8.2/ 1/ 8.	8.0/ 1/ 8.	7.8/ 1/ 8.	7.3/ 1/ 7.
CO SAMPLE METER/RANGE/PPM	63.2/13/ 61.	40.7/13/ 38.	30.5/13/ 28.	48.2/13/ 45.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.3/13/ 0.	.2/13/ 0.	.6/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	23.3/ 3/ .38	30.8/ 3/ .51	67.6/ 3/ 1.22	23.3/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	3.0/ 3/ .05	2.9/ 3/ .04	3.1/ 3/ .05	3.1/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	28.2/ 2/ 28.	33.2/ 2/ 33.	85.8/ 2/ 86.	30.0/ 2/ 30.
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ 1.	.7/ 2/ 1.	.9/ 2/ 1.	1.0/ 2/ 1.
DILUTION FACTOR	34.71	26.01	10.98	34.92
HC CONCENTRATION PPM	13.	8.	12.	4.
CO CONCENTRATION PPM	59.	37.	27.	44.
CO2 CONCENTRATION PCT	.33	.47	1.17	.33
NOX CONCENTRATION PPM	27.5	32.5	85.0	29.0
HC MASS GRAMS	2.18	1.48	2.13	.76
CO MASS GRAMS	20.59	12.98	9.65	15.40
CO2 MASS GRAMS	1839.2	2610.2	6663.9	1842.7
NOX MASS GRAMS	15.85	18.98	50.46	16.83
FUEL KG (LB)	.662 (1.46)	.929 (2.05)	2.358 (5.20)	.659 (1.45)
KW HR (HP HR)	2.13 (2.86)	2.79 (3.74)	8.50 (11.40)	2.06 (2.76)
BSHC G/KW HR (G/HP HR)	1.02 (.76)	.53 (.39)	.25 (.19)	.37 (.28)
BSCO G/KW HR (G/HP HR)	9.65 (7.20)	4.65 (3.47)	1.14 (.85)	7.48 (5.58)
BSCO2 G/KW HR (G/HP HR)	862.36 (643.06)	935.91 (697.91)	783.90 (584.55)	895.32 (667.64)
BSNOX G/KW HR (G/HP HR)	7.43 (5.54)	6.81 (5.07)	5.94 (4.43)	8.18 (6.10)
BSFC KG/KW HR (LB/HP HR)	.311 (.511)	.333 (.548)	.277 (.456)	.320 (.527)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.48 (20.76)
BSHC G/KW HR (G/HP HR)	.42 (.32)
BSCO G/KW HR (G/HP HR)	3.79 (2.82)
BSCO2 G/KW HR (G/HP HR)	837. (624.)
BSNOX G/KW HR (G/HP HR)	6.60 (4.92) Bag
BSFC KG/KW HR (LB/HP HR)	.298 (.489)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES

GRAMS/TEST	15.13
G/KWHR(G/HPHR)	.98 (.73)
G/KG FUEL (G/LB FUEL)	3.28 (1.49)
FILTER EFF.	97.0

TABLE E-8. ENGINE EMISSION RESULTS
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-38 RUN5
DATE 6/14/82
TIME
DYNO NO. 4

DIESEL EM-510-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)

RELATIVE HUMIDITY , ENGINE-50. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 8.5 GM/KG(59.5 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.17 (2160.1)	60.24 (2127.1)	61.19 (2160.7)	61.18 (2160.2)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.83)	.05 (1.83)	.05 (1.83)	.05 (1.83)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	302.0 (10662.)	301.4 (10641.)	311.2 (10989.)	303.9 (10731.)
HC SAMPLE METER/RANGE/PPM	23.8/11/ 24.	13.6/11/ 14.	17.2/11/ 17.	12.8/11/ 13.
HC BCKGRD METER/RANGE/PPM	6.2/ 1/ 6.	6.0/ 1/ 6.	6.0/ 1/ 6.	6.4/ 1/ 6.
CO SAMPLE METER/RANGE/PPM	64.5/13/ 62.	41.9/13/ 39.	30.3/13/ 28.	48.1/13/ 45.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.8/13/ 1.	.8/13/ 1.	.7/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	24.0/ 3/ .39	31.6/ 3/ .52	67.9/ 3/ 1.22	23.5/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	2.9/ 3/ .04	3.1/ 3/ .05	3.2/ 3/ .05	3.2/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	11.1/13/ 33.	13.1/13/ 39.	34.9/13/ 105.	12.1/13/ 36.
NOX BCKGRD METER/RANGE/PPM	.8/ 2/ 1.	1.1/ 2/ 1.	1.2/ 2/ 1.	1.2/ 2/ 1.
DILUTION FACTOR	33.61	25.31	10.93	34.60
HC CONCENTRATION PPM	18.	8.	12.	7.
CO CONCENTRATION PPM	60.	37.	26.	43.
CO2 CONCENTRATION PCT	.35	.48	1.18	.33
NOX CONCENTRATION PPM	32.5	38.3	103.5	35.2
HC MASS GRAMS	3.10	1.37	2.12	1.16
CO MASS GRAMS	21.11	13.07	9.43	15.37
CO2 MASS GRAMS	1919.3	2641.1	6706.7	1858.4
NOX MASS GRAMS	18.77	22.05	61.59	20.48
FUEL KG (LB)	.692 (1.53)	.940 (2.07)	2.373 (5.23)	.665 (1.47)
KW HR (HP HR)	2.16 (2.90)	2.83 (3.79)	8.58 (11.50)	2.09 (2.80)
BSHC G/KW HR (G/HP HR)	1.43 (1.07)	.48 (.36)	.25 (.18)	.55 (.41)
BSCO G/KW HR (G/HP HR)	9.76 (7.28)	4.63 (3.45)	1.10 (.82)	7.36 (5.49)
BSCO2 G/KW HR (G/HP HR)	887.54 (661.84)	934.50 (696.85)	782.08 (583.19)	890.04 (663.70)
BSNOX G/KW HR (G/HP HR)	8.68 (6.47)	7.80 (5.82)	7.18 (5.36)	9.81 (7.32)
BSFC KG/KW HR (LB/HP HR)	.320 (.526)	.333 (.547)	.277 (.455)	.319 (.524)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.65 (20.99)
BSHC G/KW HR (G/HP HR)	.49 (.37)
BSCO G/KW HR (G/HP HR)	3.77 (2.81)
BSCO2 G/KW HR (G/HP HR)	839. (625.)
BSNOX G/KW HR (G/HP HR)	7.85 (5.86)
BSFC KG/KW HR (LB/HP HR)	.298 (.490)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	12.49
	G/KWHR(G/HPHR)	.80 (.60)
	G/KG FUEL (G/LB FUEL)	2.68 (1.21)
	FILTER EFF.	96.1

TABLE E-8 (Cont'd). ENGINE EMISSION RESULTS - BAG NO_x
H-TRANS.

PROJECT NO. 05-5830-014

ENGINE NO.D3
ENGINE MODEL 0 MACK EM6-300
ENGINE 0.0 L(0. CID) I-6
CVS NO. 11

TEST NO.D3-38 RUN5
DATE 6/14/82
TIME
DYNO NO. 4

DIESEL EM-510-F
BAG CART NO. 1

BAROMETER 741.17 MM HG(29.18 IN HG)
DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)

RELATIVE HUMIDITY , ENGINE-50. PCT , CVS-60. PCT
ABSOLUTE HUMIDITY 8.5 GM/KG(59.5 GRAINS/LB) NOX HUMIDITY C.F. 1.0000

BAG RESULTS

BAG NUMBER	1	2	3	4
DESCRIPTION	NYNF	LANF	LAF	NYNF
TIME SECONDS	295.9	299.9	304.9	297.8
TOT. BLOWER RATE SCMM (SCFM)	61.17 (2160.1)	60.24 (2127.1)	61.19 (2160.7)	61.18 (2160.2)
TOT. 20X20 RATE SCMM (SCFM)	0.00 (0.0)	0.00 (0.0)	0.00(0.0)	0.00 (0.00)
TOT. 90MM RATE SCMM (SCFM)	.05 (1.83)	.05 (1.83)	.05 (1.83)	.05 (1.83)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
TOTAL FLOW STD. CU. METRES(SCF)	302.0 (10662.)	301.4 (10641.)	311.2 (10989.)	303.9 (10731.)
HC SAMPLE METER/RANGE/PPM	23.8/11/ 24.	13.6/11/ 14.	17.2/11/ 17.	12.8/11/ 13.
HC BCKGRD METER/RANGE/PPM	6.2/ 1/ 6.	6.0/ 1/ 6.	6.0/ 1/ 6.	6.4/ 1/ 6.
CO SAMPLE METER/RANGE/PPM	64.5/13/ 62.	41.9/13/ 39.	30.3/13/ 28.	48.1/13/ 45.
CO BCKGRD METER/RANGE/PPM	.6/13/ 1.	.8/13/ 1.	.8/13/ 1.	.7/13/ 1.
CO2 SAMPLE METER/RANGE/PCT	24.0/ 3/ .39	31.6/ 3/ .52	67.9/ 3/ 1.22	23.5/ 3/ .38
CO2 BCKGRD METER/RANGE/PCT	2.9/ 3/ .04	3.1/ 3/ .05	3.2/ 3/ .05	3.2/ 3/ .05
NOX SAMPLE METER/RANGE/PPM	29.7/ 2/ 30.	35.2/ 2/ 35.	88.9/ 2/ 89.	31.4/ 2/ 31.
NOX BCKGRD METER/RANGE/PPM	.8/ 2/ 1.	1.1/ 2/ 1.	1.2/ 2/ 1.	1.2/ 2/ 1.
DILUTION FACTOR	33.61	25.31	10.93	34.60
HC CONCENTRATION PPM	18.	8.	12.	7.
CO CONCENTRATION PPM	60.	37.	26.	43.
CO2 CONCENTRATION PCT	.35	.48	1.18	.33
NOX CONCENTRATION PPM	28.9	34.1	87.8	30.2
HC MASS GRAMS	3.10	1.37	2.12	1.16
CO MASS GRAMS	21.11	13.07	9.43	15.37
CO2 MASS GRAMS	1919.3	2641.1	6706.7	1858.4
NOX MASS GRAMS	16.70	19.68	52.26	17.57
FUEL KG (LB)	.692 (1.53)	.940 (2.07)	2.373 (5.23)	.665 (1.47)
KW HR (HP HR)	2.16 (2.90)	2.83 (3.79)	8.58 (11.50)	2.09 (2.80)
BSHC G/KW HR (G/HP HR)	1.43 (1.07)	.48 (.36)	.25 (.18)	.55 (.41)
BSCO G/KW HR (G/HP HR)	9.76 (7.28)	4.63 (3.45)	1.10 (.82)	7.36 (5.49)
BSCO2 G/KW HR (G/HP HR)	887.54 (661.84)	934.50 (696.85)	782.08 (583.19)	890.04 (663.70)
BSNOX G/KW HR (G/HP HR)	7.72 (5.76)	6.96 (5.19)	6.09 (4.54)	8.42 (6.28)
BSFC KG/KW HR (LB/HP HR)	.320 (.526)	.333 (.547)	.277 (.455)	.319 (.524)

TOTAL TEST RESULTS 4 BAGS

TOTAL KW HR (HP HR)	15.65 (20.99)
BSHC G/KW HR (G/HP HR)	.49 (.37)
BSCO G/KW HR (G/HP HR)	3.77 (2.81)
BSCO2 G/KW HR (G/HP HR)	839. (625.)
BSNOX G/KW HR (G/HP HR)	6.79 (5.06) Bag
BSFC KG/KW HR (LB/HP HR)	.298 (.490)

PARTICULATE RESULTS, TOTAL FOR 4 BAGS

90MM PARTICULATE RATES	GRAMS/TEST	12.49
	G/KWHR(G/HPHR)	.80 (.60)
	G/KG FUEL (G/LB FUEL)	2.68 (1.21)
	FILTER EFF.	96.1

TABLE E-9. TRANSIENT CYCLE STATISTICS AND MODAL EMISSION RATE SUMMARY

TRANSIENT CYCLE STATISTICS

	Cold Cycle			Hot Cycle		
TEST D3-35	Speed	Torque	Power	Speed	Torque	Power
Standard Error	51.4	5.1	5.9			
Slope	1.0018	0.9329	0.9599			
Corr. Coef.	0.993	0.945	0.954			
Intercept	7.1	1.5	0.8			
Points Used	1179	925	925			
Ref. Work (Dev. %)		21.77	(-5.44)			
TEST D3-36						
Standard Error	55.8	4.9	5.6	46.6	4.6	5.5
Slope		0.9524	0.9829	1.0004	0.9366	0.9684
Corr. Coef.	0.991	0.945	0.954	0.994	0.953	0.959
Intercept	4.3	1.2	0.8	10.6	6.2	1.3
Points Used	1179	902	902	1179	917	917
Ref. Work (Dev. %)		21.77	(-6.54)		21.77	(-4.62)
TEST D3-38						
Standard Error				45.8	4.8	5.7
Slope				0.9977	0.9272	0.9733
Corr. Coef.				0.994	0.950	0.956
Intercept				14.2	11.8	1.7
Points Used				1179	925	925
Ref. Work (Dev. %)					21.77	(-3.55)

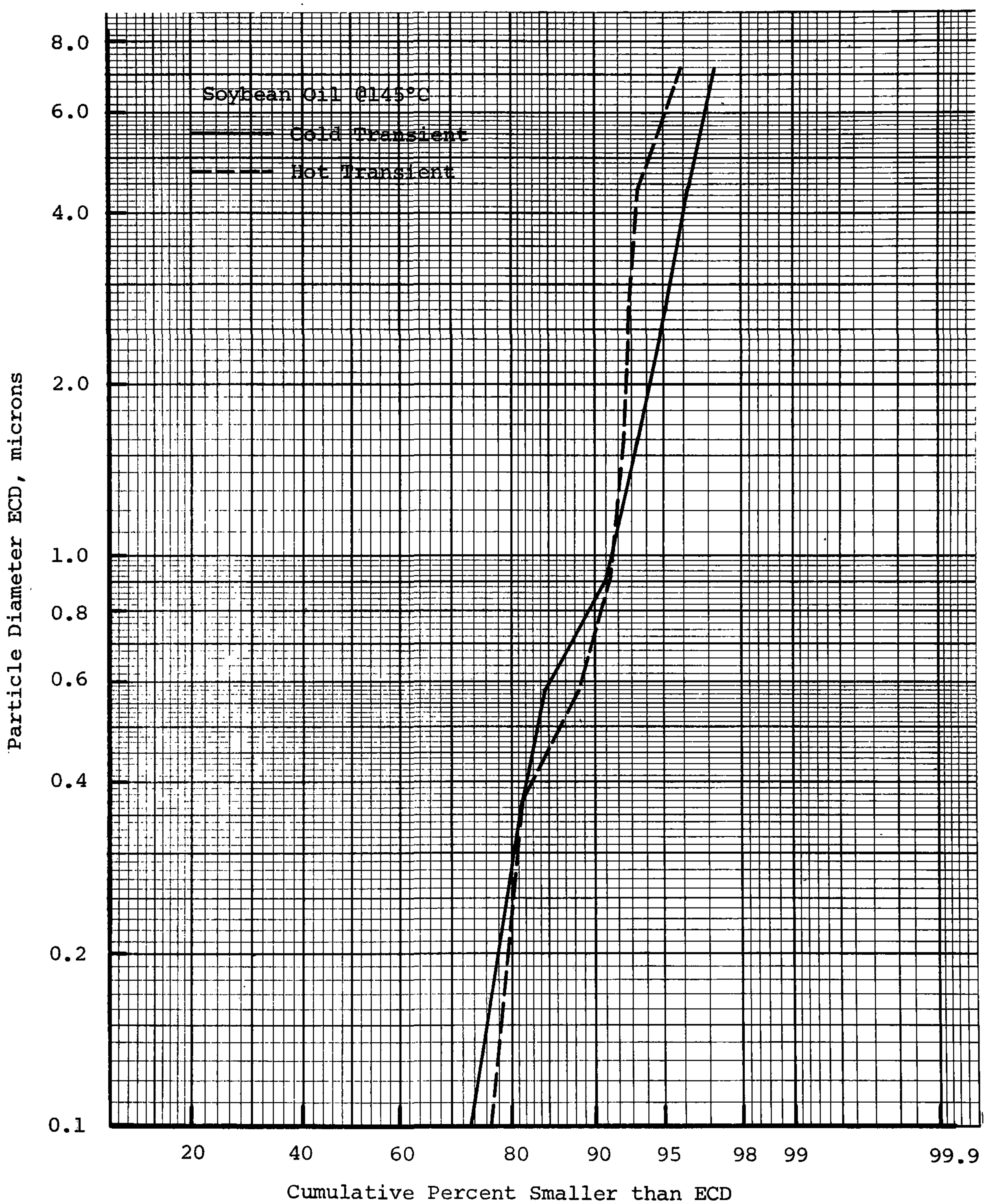

Figure E-1. Particle size distribution from transient operation of the Mack EM6-300 with soybean oil @145°C

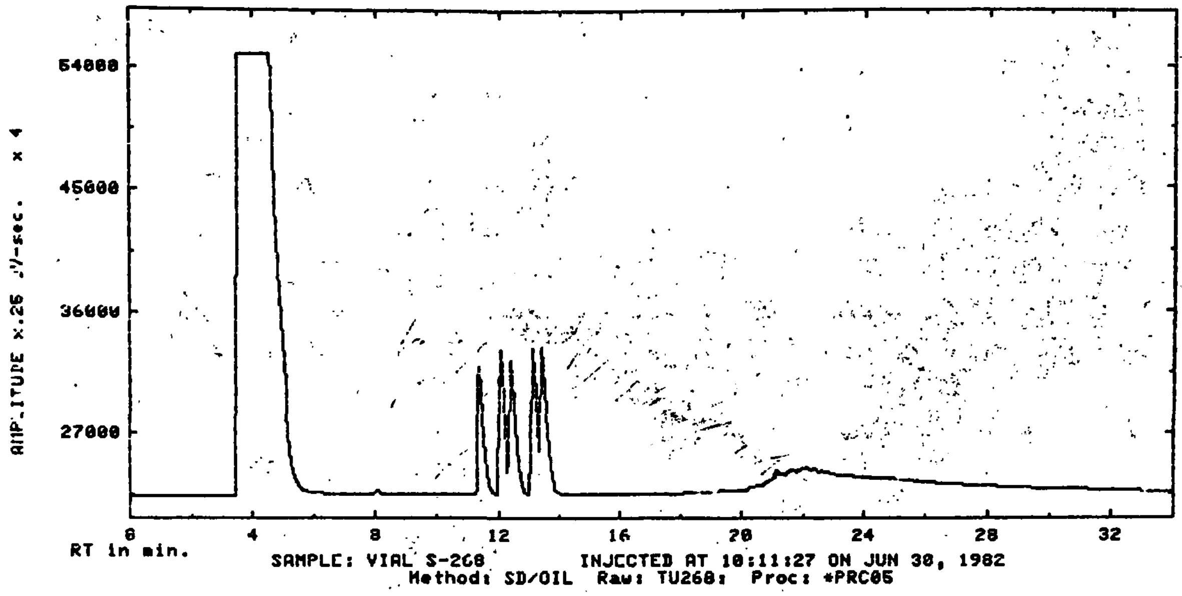

Figure E-2. Boiling Point Distribution of SOF derived from cold-start transient operation with soybean oil

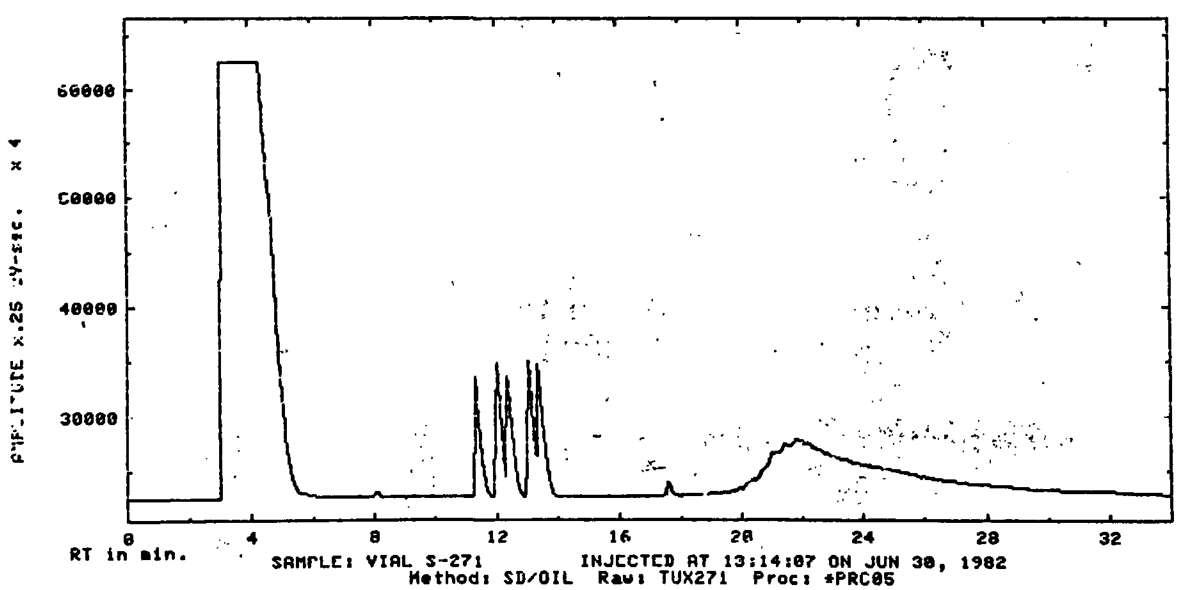

Figure E-3. Boiling Point Distribution of SOF derived from hot-start transient operation with soybean oil

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 460/3-83-004	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE HEAVY-DUTY DIESEL EMISSIONS AS A FUNCTION OF ALTERNATE FUELS		5. REPORT DATE September 1983 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Terry L. Ullman Charles T. Hare		8. PERFORMING ORGANIZATION REPORT NO.
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16. ABSTRACT

Exhaust emissions from a Mack EM6-300 heavy-duty diesel engine were characterized with five different fuels during transient and steady-state operation. A control fuel (Phillips D-2) was used for baseline emissions, and as a base stock in three alternate fuel blends containing EDS or SRC-II middle distillates or used lubricating oil. The fifth fuel tested was neat soybean oil, heated to 145°C. Emission measurements included HC, CO, CO_2, NO_x, visible smoke, particulate, IHC, aldehydes, odor (DOAS), phenols, sulfate, elemental composition, particle sizing, SOF, SOF boiling point distribution, BaP, Ames bioassay and HPLC fractionation. HC, CO, NO_x and particulate emissions were similar for this engine on all fuels tested with exception of higher particulates for the soybean oil and higher NO_x for the SRC-II blend. Ames response was highest for the EDS and SRC-II blends. The BaP level was highest for the soybean oil.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Exhaust Emissions Heavy-Duty Diesel Engines Alternate Fuels Diesel Fuels Vegetable Oil Fuel	Fuel Effects Emissions Characterization Alternate Fuels Characterization	

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