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Trial Evaluation

of

Fuel Performance Catayst - 1 (FPC-1)

by

Triangle Gas Company

Butler, Pennsylvania

May 28, 1987

Report prepared for Triangle Gas

by

UHI Corporation

Provo, Utah

and

Research Development Products

Evans City, Pennsylvania

Abstract

This paper will discuss the effect of an iron based fuel catalyst (ferrous picrate) upon fuel economy and exhaust gas emissions in a fleet of diesel powered tanker trucks operated by Triangle Gas Company, Butler, Pennsylvania. It will be shown that the catalyst can provide significant cost savings to the diesel fleet operated by Triangle Gas. It will also be shown that a test method that measures changes in the carbon containing gases in the exhaust stream is an accurate means of determining changes in fuel flow to the engine.

Introduction

An aftermarket combustion improver called Fuel Performance Catalyst - 1 (FPC-1) contains an iron based catalyst (ferrous picrate) that has been tested extensively in EPA recognized independent and university affiliated laboratories. These tests, in both gasoline and diesel powered passenger vehicles, have demonstrated that the catalyst can provide fuels savings of 2% to 10% depending upon vehicle operating parameters, equipment condition, age and mileage.

Field testing, primarily in heavy duty diesel fleets, substanciates laboratory findings and also reveals the catalyst can be an effective means of further reducing operating costs by inhibiting the buildup of hard carbon deposists on critical engine components.

This report summarizes the results of the Triangle Gas Company evaluation of the effect of FPC-1 on fuel economy in it's fleet of diesel powered tanker trucks.

Measurement of Fuel Economy - Carbon Balance vs Direct Measurement

Until late 1973, vehicle fuel economy had been determined primarily by using various test track or road test procedures. In September. 1973, the U.S. Environmental Protection Agency (EPA) introduced a method of determining vehicle fuel economy in conjunction with its chassis dynamometer emissions test. This method determines fuel consumption based upon vehicle exhaust emissions through a "carbon balance" calculation rather than a direct measurement of fuel consumed.

Starting in 1974, the carbon balance method was used solely in the EPA, CVS cold start emissions test cycle (LA-4 Cycle). In 1975, the cycle was modified adding a hot start (FTP). Later, a highway test was also developed (HFET).

A series of tests done by Ford Motor Company compared the traditional fuel measurement techniques (volumetric or gravimetric) to the carbon balance method. The results, published in SAE Technical Paper Series 75002 (EXHIBIT A) entitled "Improving the Measurement of Chassis Dynamometer Fuel Economy", confirmed

> "fuel economy results obtained by carbon mass balance calculation of carbon containing components in the vehicle exhaust are at least as accurate and repeatable as those obtained by direct fuel measurement of fuel consumed."

The Ford Motor study determined that the most important factors in the measurement of fuel consumption with the carbon balance method are:

* For fuel consumption, the measurement of CO2

* For distance traveled, the dynamometer to vehicle interface conditions, precision and manner in which the vehicle is driven

* Use of standardized test equipment and procedures, calibration and ambient condition correction methods.

The exhaust gas analysis/carbon balance technique of determining fuel consumption changes used by RDP and UHI personnel uses a state-of-the-art, non-dispersive infrared (NDIR) exhaust gas analyzer made by Sun Electric Corporation, to measure CO2 and other carbon containing exhaust gases. The Sun Electric SGA-9000 Exhaust Gas Analyzer is approved by the EPA for vehicle emissions analysis. The SGA-9000 is calibrated internally using Scotty Calibration Gases as recommended by Sun Electric. A SGA-9000 brochure with instrument specifications is attached in Exhibit B.

The method used by UHI and RDP does not require that the vehicle travel, nor does the vehicle interface with a chassis dynamometer during testing. Consequently, inaccuracies created by improper dynamometer to vehicle interfacing and errors in driving do not exist. Further, a miles per gallon figure is not given as a result. This method measures fuel flow to the engine at a specified load and rpm, and makes comparisons on a percentage basis between the consumption of control fuel (not treated with FPC-1) and the FPC-1 treated fuel at that load.

Ambient conditions are not corrected for in this method since studies by Ford Motor show ambient conditions have a maximum variability effect of only 0.6% on CO2 readings.

Although, not as controlled as an EPA laboratory test, the carbon balance method utilized by UHI is the most accurate and practical means of measuring fuel consumption changes in the field.

Additionally, the carbon balance method has consistently proven to be more accurate then monthly mpg fleet records.

The technique measures exhaust concentrations of carbon dioxide (CO2), carbon monoxide (CO), oxygen (O2), and unburned hydrocarbons (HC). Exhaust gas temperature is also measured and engine load is determined from engine tachometer readings.

Methodology

The fleet of eight diesel powered tanker trucks owned and operated by Triangle Gasoline Company was selected as the test fleet.

After calibrating the SGA-9000 analyzer and the IMC thermocouple, and performing a leak test on the sampling hose and connections, each truck engine was brought up to stable operating temperature as verified with engine water temperature and exhaust temperature. No exhaust data was recorded until each truck engine had stabilized.

The fleet was first tested, operating at 1900 rpm, followed by a test at 1600 rpm. Readings of CO2, CO, HC (measured as CH4), O2 and exhaust temperature were taken at approximately 30 second intervals.

After recording the first two readings, the SGA-9000 auto calibrating button was depressed and the instrument "checked itself" to prevent any drift. This self checking procedure was repeated after each set of two data points throughout the entire 1900 and 1600 rpm test. Several readings were taken on each truck and at each rpm. The data sheets are enclosed in Exhibit C.

After control testing, the fuel storage tank from which the Triangle fleet is exclusively fueled, was treated with FPC-1 at the recommended 1 to 1600 ratio (1 oz. FPC-1 to 12.5 gallons diesel). This took place on the evening of April 16, 1987.

On May 20, 1987, after accumulating a fleet average of 5,261 miles per truck with FPC-1 treated fuel, the above procedure was repeated. The treated fuel data sheets are attached in Exhibit D.

All fuel used during the baseline and treated test segments was #2 diesel purchased through the same fuel supplier.

Special Note:

1.) The test procedure calls for a sequence of rpm testing at 1900 and 1600 rpm, on the same equipment, to show that the change in fuel flow between the two loads can be demonstrated with the SGA-9000 Exhaust Gas Analyzer. It is obvious that a drop in fuel consumption will occur when reducing rpm from 1900 to 1600 and it shows up readily during the baseline test. This validates the concept of fuel flow measurement with exhaust gas analysis.

2.) The 1900 rpm load is more indicative of actual engine operation and improvements at this rpm are more meaningful.

3.) After having completed treated fuel testing on eight of the nine trucks in the Triangle fleet, a leak was detected in the SGA-9000 sampling hose. Several of the trucks were retested to determine the percent of dilution in the exhaust gases caused by the leak. The percent dilution was determined to be an absolute .3% CO2 and all CO2 readings were corrected. The correction resulted in a decrease in the overall fuel savings demonstrated by the addition of the catalyst.

4.) A qualitative technique for determining reductions in smoke and particulate was performed during both control and treated fuel test segments. This was done by attaching a new 25 micron filter to the SGA-9000 sampling hose at the beginning of each test segment. The filter traps unburned fuel that is exhausted from the engine as particulate or soot. A comparison of the control fuel and treated fuel filters revealed that the fuel was burning much cleaner with FPC-1 as particulate volume was visibly reduced in the treated fuel filter. The control test segment involved ninety minutes of sampling; the treated segment lasted one hundred and five minutes.

Equipment List

Unit #	Make	Engine	Mileage
116	Cummins	400	240,490
114	Cummins	400	113,792
112	Cummins	350	27,459
117	Cummins	350	83,926
102	Detroit	430	491,188
101	Detroit	430	613,849
115	Detroit	430	474,779
30	Mack	673	178,101

Summary

The data from the 1900 rpm test control and treated fuel is summarized on Table I. The 1600 rpm data is summarized on Table II.

Table I

Summary of Exhaust Gas Data at 1900 RPM

	CO	HC	CO2	O2	Exh. Temp.
Control	0.026%	19.70ppm	2.17%	18.48%	331.8 * F
Treated	0.025%	20.10ppm	2.00%	18.63%	331.5 * F

Table II

Summary of Exhaust Gas Data at 1600 RPM

	CO	HC	CO2	O2	Exh. Temp.
Control	0.026%	25.15ppm	1.81%	18.86%	297.7 *F
Treated	0.025%	21.20ppm	1.71%	19.00%	298.9 *F

From the above data, volume fractions can be easily calculated and weighed using the known molecular weight of each gas. A total molecular weight and engine performance factor can then be calculated from which fuel consumption changes can be determined. The volume fractions, total molecular weights, and engine performance factors for the 1900 rpm data are found on Table III. The same for the 1600 rpm data are found on Table IV. The engineering formuli from which these are calculated are found in Exhibit E.

Table III

Volume Fractions for the 1900 RPM Data

	Control	Treated
VfCO	0.00026	0.00025
VfHC	0.0000197	0.0000201
VfCO2	0.0217	0.0200
VfO2	0.1848	0.1863

Total Molecular Weight and Performance Factors

Table IV

Volume Fractions for the 1600 RPM Data

	Control	Treated
VFCO	0.00026	0.00025
VFHC	0.00002515	0.00002120
VFCO2	0.0181	0.0171
VFO2	0.1886	0.1900

Total Molecular Weights and Performance Factors

Mwt1	29.05	Mwt2	29.03
pf1	333423.31	pf2	353624.46
PF1	210523.48	PF2	223258.55

Percent Change in Fuel Flow

$$223258.55 - 210523.48 = 12735.07$$

$$\frac{12735.07}{210523.48} \times 100 = +6.05\%$$

Conclusion

Based upon the data gathered during exhaust gas testing with and without the FPC-1 Fuel Performance Catalyst, the addition of FPC-1 to the fuel used by the Triangle Gas test fleet created an average 8.26% reduction in fuel consumed at 1900 rpm and an average 6.05% reduction in fuel consumption at 1600 rpm.

Additionally, the catalyst treated fuel burned cleaner as demonstrated by the comparison of the control and treated fuel sampling hose filters. Photographs of the filters are found in Exhibit F.

Baseline Treated

TRIANGLE GASOLINE CO., OF BUTLER

DISTRIBUTORS OF
GASOLINE, FUEL AND KENDALL LUBRICANTS
1100 NORTH MAIN STREET EXTENSION
P. O. BOX 30 BUTLER, PENNA. 16001

PHONE 283-0750

EARL C. ZINN DAVID E. ZINN

August 11, 1987

Mr. Lee Pope
U H I Corp.
750 North 200 W Suite 306
Provo, UT 84601

Dear Mr. Pope:

As a company, we have been selling #2 Fuel for probably twenty years and during that time never once have we ever used or offered for sale, an additive of any type.

About two years ago your salesman, Mr. Ed Nusser, called on us and asked if we would place your product, FPC-1, in the fuel oil of one of our customers, namely Armco Inc. Needless to say, at that point we were skeptical but agreed to do it anyway as a favor to Armco. Time passed and Ed again called on us, only this time he wanted to run a test on our own fleet using FPC-1. Again, we were skeptical but went ahead. As a result of this test, and the quality of the test equipment, we were most impressed. Probably the biggest factor was the cleanliness of the filtration unit in the test equipment after the months usage of FPC-1. In addition, our records showed an approximate 7% savings in fuel mileage on our over all fleet. At this time, Ed approached us about distributing the product within our sales area and as you know, we are doing just that.

We feel that given some time and reasonable effort, the product will definitely become an important part of fleet maintanance for our customers as well as a good profit item for us. We are excited about your product and hope to become one of your most successful distributors.

Yours truly,

Triangle Gasoline Company

David E. Zinn
President

DEZ/nr

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Exhaust Gas Analysis Form

Name of Company TRIANGLE OIL

Date of Test APRIL 16, 1987

Type of Equipment Tested

Engine Type and Specs MACK 673 T

Identification No. 30 Milage 176001

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.05	34	2.86	17.4	348	1900
2.	.05	36	2.84	17.4	350	1900
3.	.05	35	2.78	18.5	354	1900
4.	.04	35	2.77	17.7	354	1900
5.	.04	35	2.77	17.7	354	1900
6.	.05	35	2.26	18.2	302	1600
7.	.05	35	2.26	18.2	299	1600
8.	.05	35	2.28	18.5	299	1600
9.	.05	36	2.28	18.2	304	1600
10.	.05	37	2.28	18.2	301	1600

Length of Test in minutes 11 mins

Signature of Technicians

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417

RIGHT Side Exh

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test 4-17-87

Type of Equipment Tested

Engine Type and Specs 400 cum Turbo

Identification No. 116 Milage 240 490

Type of Test

Ambient Air Temp. 53

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	22	2.14	18.7	~~387~~ 368	1900
2.	.03	22	2.17	18.4	367	1900
3.	.03	22	2.15	19.0	366	1900
4.	.03	22	2.15	18.5	366	1900
5.	.03	23	2.14	19.0	363	1900
6.	.03	24	1.91	18.7	321	1600
7.	.03	24	1.89	18.7	319	1600
8.	.03	24	1.87	19.2	323	1600
9.	.03	23	1.90	18.8	324	1600
10.	.03	24	1.87	19.7	323	1600

Length of Test in minutes 9

Signature of Technicians

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903

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test 4-16-87

Type of Equipment Tested

Engine Type and Specs 400 CUMMINS TURBO

Identification No. 114 Milage 113792

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	28	1.71	19.5	355	1900
2.	.03	28	1.70	18.9	356	1900
3.	.03	28	1.72	19.4	356	1900
4.	.03	29	1.70	18.9	355	1900
5.	.03	28	1.72	18.8	357	1900
6.	.03	29	1.43	19.1	332	1600
7.	.03	27	1.42	19.1	332	1600
8.	.03	28	1.48	19.3	332	1600
9.	.02	28	1.51	19.1	332	1600
10.	.03	28	1.51	19.3	331	1600

Length of Test in minutes 9

Signature of Technicians

cold

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9/7

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test 4-17-87

Type of Equipment Tested

Engine Type and Specs 440 DET. TURBO

Identification No. 102 Milage 49188

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.02	22	1.99	18.3	290	1900
2.	.02	24	2.04	18.3	291	1900
3.	~~.02~~ .02	~~15~~ 15	~~1.71~~ 1.74	~~19.0~~ 18.7	~~292~~ 293	1900
4.	.02	15	1.76	18.6	291	1900
5.	.02	13	1.71	18.7	292	1900
6.	.02	17	1.35	19.1	254	1600
7.	.02	18	1.33	19.1	253	1600
8.	.02	23	1.35	19.5	254	1600
9.	.02	23	1.35	19.1	253	1600
10.	.02	21	1.33	19.4	254	1600

Length of Test in minutes 9

Signature of Technicians

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Exhaust Gas Analysis Form

Name of Company TRIANGLE OIL

Date of Test APRIL 16, 1987

Type of Equipment Tested

Engine Type and Specs 350 cummins TURBO

Identification No. 117 Milage 83926

Type of Test

Ambient Air Temp. 47°

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	29	1.96	18.3	351	1900
2.	.02	31	1.90	18.4	353	1900
3.	.03	28	1.89	19.0	354	1900
4.	.03	29	1.89	18.7	357	1900
5.	.03	28	1.89	19.2	358	1900
6.	.02	26	1.64	19.0	332	1600
7.	.02	26	1.64	19.0	334	1600
8.	.02	26	1.63	19.4	335	1600
9.	.02	26	1.64	18.9	334	1600
10.	.02	26	1.64	19.1	333	1600

Length of Test in minutes 11 min

Signature of Technicians

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Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test 4-16-87

Type of Equipment Tested

Engine Type and Specs 350 CUMMINS TURBO

Identification No. 112 Milage 027459

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	22	2.41	18.0	356	1900
2.	03	22	2.44	17.9	356	1900
3.	.02	21	2.40	18.2	353	1900
4.	02	21	2.42	18.1	351	1900
5.	02	22	2.42	18.0	357	1900
6.	02	24	1.89	18.7	310	~~1600~~ 1550
7.	02	24	1.89	18.7	309	~~1600~~ 1550
8.	02	24	1.89	18.7	309	~~1600~~ 1550
9.	02	22	1.87	18.9	308	~~1600~~ 1550
10.	02	23	1.87	18.7	307	~~1600~~ 1550

Length of Test in minutes 12 MIN

Signature of Technicians

12?

729

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Exhaust Gas Analysis Form

Name of Company TRIANGLE OIL

Date of Test 4-16-87

Type of Equipment Tested

Engine Type and Specs 892 430 DET D TURBO

Identification No. 101 Milage 6138490 H.B

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.01	22	1.95	18.6	269	1900
2.	.01	22	1.94	18.6	270	1900
3.	.02	22	1.93	19.5	269	1900
4.	.02	22	1.93	18.7	269	1900
5.	.01	22	1.92	19.2	271	1900
6.	.02	22	1.71	18.8	250	1600
7.	.02	22	1.71	18.8	250	1600
8.	.02	24	1.70	18.9	248	1600
9.	.02	24	1.70	18.9	247	1600
10.	.02	23	1.71	19.4	246	1600

Length of Test in minutes 11

Signature of Technicians

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857
9004

Exhaust Gas Analysis Form

Name of Company TRIANGLE

Date of Test 4-17-87

Type of Equipment Tested

Engine Type and Specs 430 PET TURBO

Identification No. 115 Milage 474779

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.02	22	2.62	18.0	309	1900
2.	.02	24	2.61	17.9	311	1900
3.	.02	22	2.56	18.4	310	1900
4.	.02	19	2.56	18.0	311	1900
5.	.02	19	2.56	17.9	310	1900
6.	.02	22	2.29	18.4	281	1600
7.	.02	22	2.23	18.4	283	1600
8.	.02	22	2.30	18.9	285	1600
9.	.02	22	2.26	18.4	283	1600
10.	.02	22	2.24	19.0	281	1600

Length of Test in minutes 8

Signature of Technicians

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6.18

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test MAY 20, 87

Type of Equipment Tested

Engine Type and Specs 350 CUMMINS TURBO

Identification No. + 112 Milage 31708 (4600)

Type of Test

Ambient Air Temp.

BAD FUEL PUMP

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	17 2.16	1.86	18.7	~~360~~ 366	1900
2.	.02	17 2.15	1.85	18.4	366	1900
3.	.02	18 2.14	1.84	18.4	372	1900
4.	.02	18 2.14	1.84	18.4	371	1900
5.	.03	18 2.13	1.83	19.0	372	1900
6.	.02	18 1.71	1.47	28.8	307	~~1600~~ 1550
7.	.02	18 1.73	1.45	18.8	309	~~1600~~ 1550
8.	.02	18 1.76	1.46	18.9	309	~~1600~~ 1550
9.	.02	18 1.77	1.47	18.6	311	~~1600~~ 1550
10.	.03	22 1.75	1.45	18.8	314	~~1600~~ 1550

Length of Test in minutes 14 min

Signature of Technicians

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6.11
6.02

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test MAY 20, 1987

Type of Equipment Tested

Engine Type and Specs 440 D=T TURBO

Identification No. 102 Milage 493609 ✓ (2,000)

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O_2	Exh. Temp.	RPM
1.	.02	15	1.55	18.9	270	1900
2.	.02	17	1.56	18.8	272	1900
3.	.02	17	1.52	19.2	273	1900
4.	.02	17	1.52	18.8	274	1900
5.	.02	17	1.49	18.9	274	1900
6.	.02	18	1.18	19.5	245	1600
7.	.02	18	1.20	19.1	245	1600
8.	.02	17	1.18	19.4	243	1600
9.	.02	17	1.18	19.2	243	1600
10.	.02	19	1.18	19.4	243	1600

Length of Test in minutes 9 min

Signature of Technicians

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505

Exhaust Gas Analysis Form

Name of Company TRIANGLE

Date of Test MAY 20, 1987

Type of Equipment Tested

Engine Type and Specs 892 430 DET D TURBO

HUB

Identification No. - 101 Milage ~~[illegible]~~ 620 1290

Type of Test (7,000)

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.01	15 (98)	1.63	18.9	269	1900
2.	.01	17 (01)	1.71	18.6	271	1900
3.	.01	18 (97)	1.67	19.0	272	1900
4.	.01	17 (97)	1.67	18.7	274	1900
5.	.01	17 (93)	1.63	19.0	275	1900
6.	.02	18 (74)	1.44	19.2	253	1600
7.	.02	17 (72)	1.42	18.9	248	1600
8.	.02	19 (72)	1.42	19.3	256	1600
9.	.02	18 (72)	1.42	18.9	256	1600
10.	.02	19 (72)	1.43	19.3	255	1600

Length of Test in minutes 9 min

Signature of Technicians

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Exhaust Gas Analysis Form

Name of Company TRIANGLE

Date of Test 4-20-87

Type of Equipment Tested

Engine Type and Specs 430 DET TURBO

Identification No. 115 Milage ~~474799~~ 48674 (1,000)

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.02	20	2.31	17.7	309	1900
2.	.02	20	2.29	17.7	311	1900
3.	.02	20	2.14	18.5	310	1900
4.	.02	19	2.10	18.0	311	1900
5.	.02	18	2.09	18.1	316	1900
6.	.01	17	1.86	18.3	281	1600
7.	.01	17	1.82	18.4	283	1600
8.	.02	20	1.86	19.2	285	1600
9.	.02	17	1.86	18.5	283	1600
10.	.02	17	1.85	18.4	281	1600

Length of Test in minutes

Signature of Technicians

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Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test MAY 20, 1987

Type of Equipment Tested

Engine Type and Specs 350 CUMMINS TURBO

Identification No. # 117 O.K. Milage 90 658 (7000)

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	27	1.80	19.3	364	1900
2.	.03	26	1.80	18.4	368	1900
3.	'03	27	1.75	19.2	364	1900
4.	.03	27	1.75	18.5	363	1900
5.	.03	26	1.76	18.5	363	1900
6.	.03	27	1.51	19.4	337	1600
7.	.02	26	1.51	19.0	337	1600
8.	.02	26	1.51	18.8	335	1600
9.	.03	27	1.51	19.5	335	1600
10.	.02	26	1.51	18.9	333	1600

Length of Test in minutes

Signature of Technicians

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5.39
5.46

Exhaust Gas Analysis Form

Name of Company TRIANGLE

Date of Test MAY 20, 87

Type of Equipment Tested

Engine Type and Specs 400 CUMMINS TURBO

Identification No. — 114 Milage ~~120725~~ 120749

Type of Test (7,006)

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	02	Exh. Temp.	RPM
1.	03	21	1.48	18.9	370	1900
2.	.03	21	1.46	18.9	368	1900
3.	.03	24	1.44	19.1	369	1900
4.	.03	24	1.43	19.0	367	1900
5.	.03	23	1.43	19.0	369	1900
6.	.03	24	1.22	19.4	340	1600
7.	.03	23	1.22	19.1	340	1600
8.	.03	25	1.22	19.3	339	1600
9.	.03	24	1.20	19.1	339	1600
10.	.03	25	1.21	19.2	336	1600

Length of Test in minutes 10 min

Signature of Technicians

Research Development Products • P.O. Box 53, Evans City, PA 16033 • 412/538-8842

7:60 8:00 8:10

RIGHT SIDE EXT

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test MAY 20, 1987

Type of Equipment Tested

Engine Type and Specs

Identification No. + 116 ok Milage 246 950 (6,000)

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	19	1.66	18.6	338	1900
2.	.03	19	1.66	18.5	340	1900
3.	.04	19	1.64	19.4	341	1900
4.	.03	19	1.66	18.6	341	1900
5.	.03	20	1.66	19.1	342	1900
6.	.03	23	1.51	19.6	314	1600
7.	.03	19	1.51	18.9	315	1600
8.	.03	19	1.51	19.4	316	1600
9.	.03	19	1.52	18.8	315	1600
10.	.03	23	1.55	19.2	314	1600

Length of Test in minutes min

Signature of Technicians

Research Development Products • P.O. Box 53, Evans City, PA 16033 • 412/538-8842

5:01
4:58

Exhaust Gas Analysis Form

Name of Company TRIANGLE OIL

Date of Test MAY 20, 1987

Type of Equipment Tested

Engine Type and Specs MACK 673

Identification No. #30 Milage 178,101 (2,100)

Type of Test

Ambient Air Temp. 67

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.04	19 2.45	2.15	18.0	351	1900
2.	.04	23 2.44	2.14	17.9	355	1900
3.	.04	22 2.38	2.08	18.3	353	1900
4.	.04	23 2.38	2.08	18.1	355	1900
5.	.04	25 2.38	2.08	18.3	356	1900
6.	.04	26 2.0	1.70	18.6	313	1600
7.	.04	26 2.0	1.70	18.9	313	1600
8.	.04	26 2.0	1.70	18.6	312	1600
9.	.04	26 1.99	16.9	18.8	312	1600
10.	.04	26 2.0	1.70	18.6	311	1600

Length of Test in minutes 9 min

Signature of Technicians

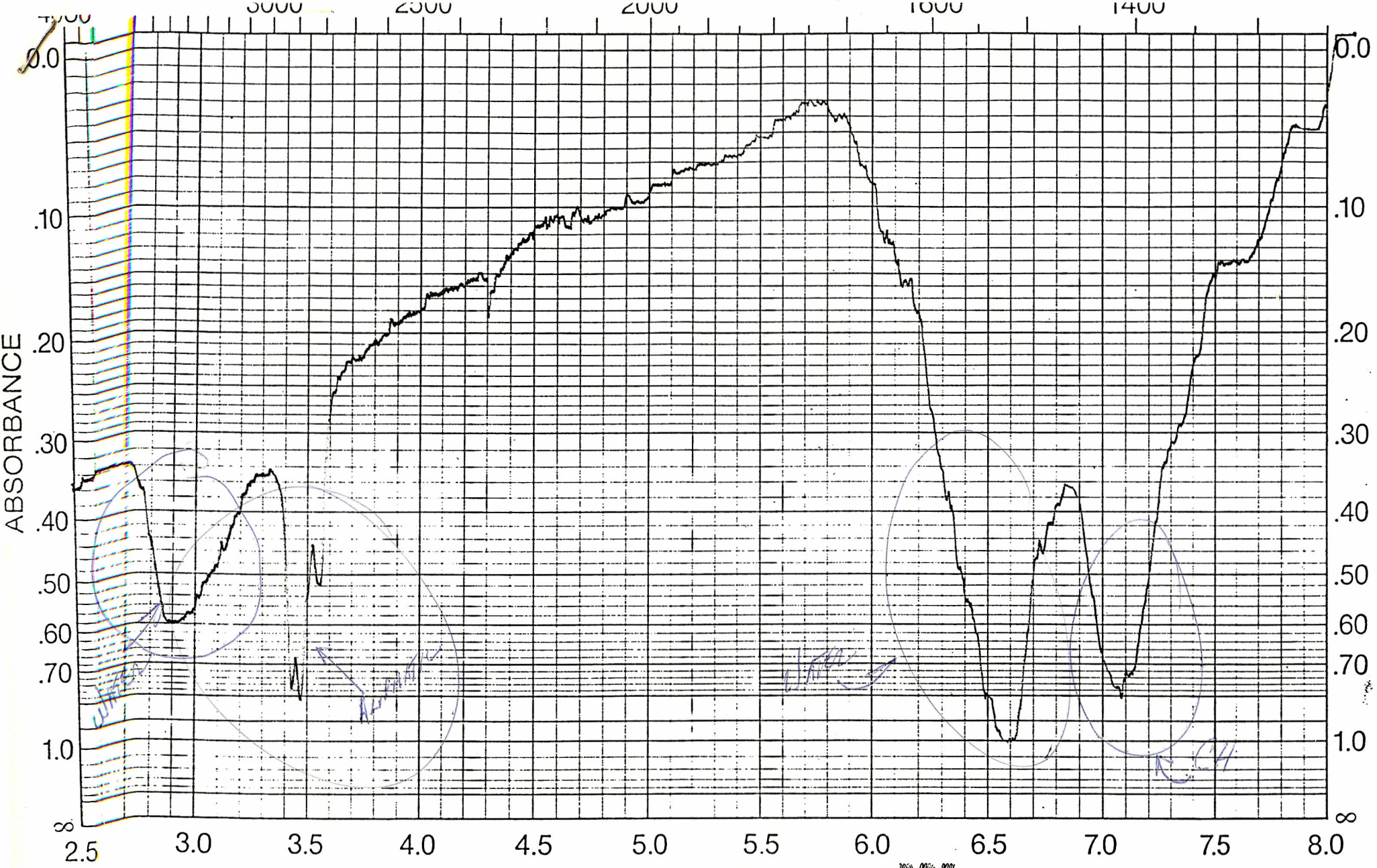
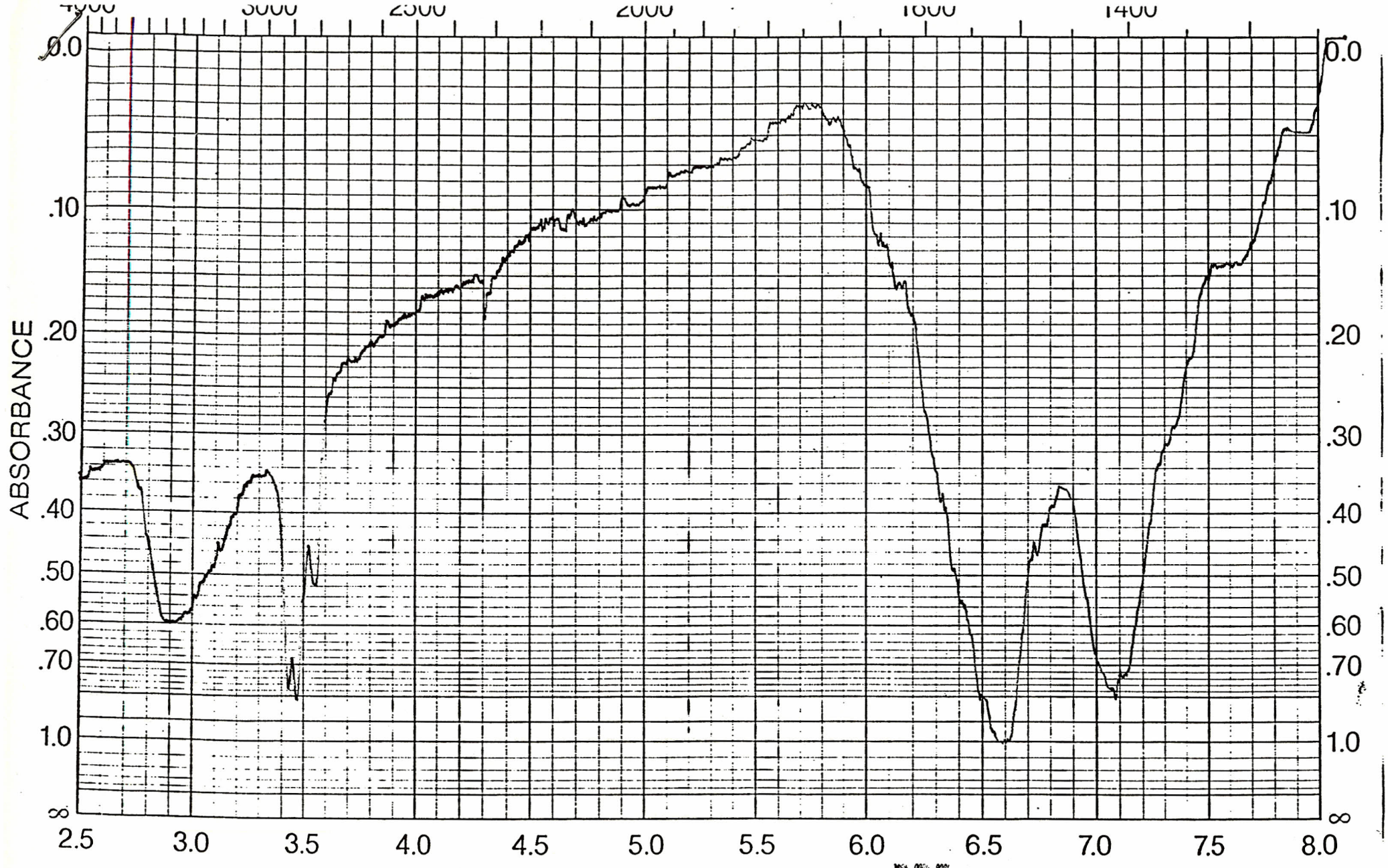


CHART NO. WGPE 237-1028

WILMAD GLASS CO., INC.
U.S. Route 40 and Oak Road
BUENA, N.J. 08310 U.S.A.

Printed in U.S.A. 10-78/50/WP

SAMPLE gas filter	CURVE NO.	SCAN SPEED fast	OPERATOR
	CONC.	SLIT 6	DATE
ORIGIN	CELL PATH	REMARKS	



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SAMPLE gas filter	CURVE NO.	SCAN SPEED fast	OPERATOR
	CONC.	SLIT 6	DATE
ORIGIN	CELL PATH	REMARKS	

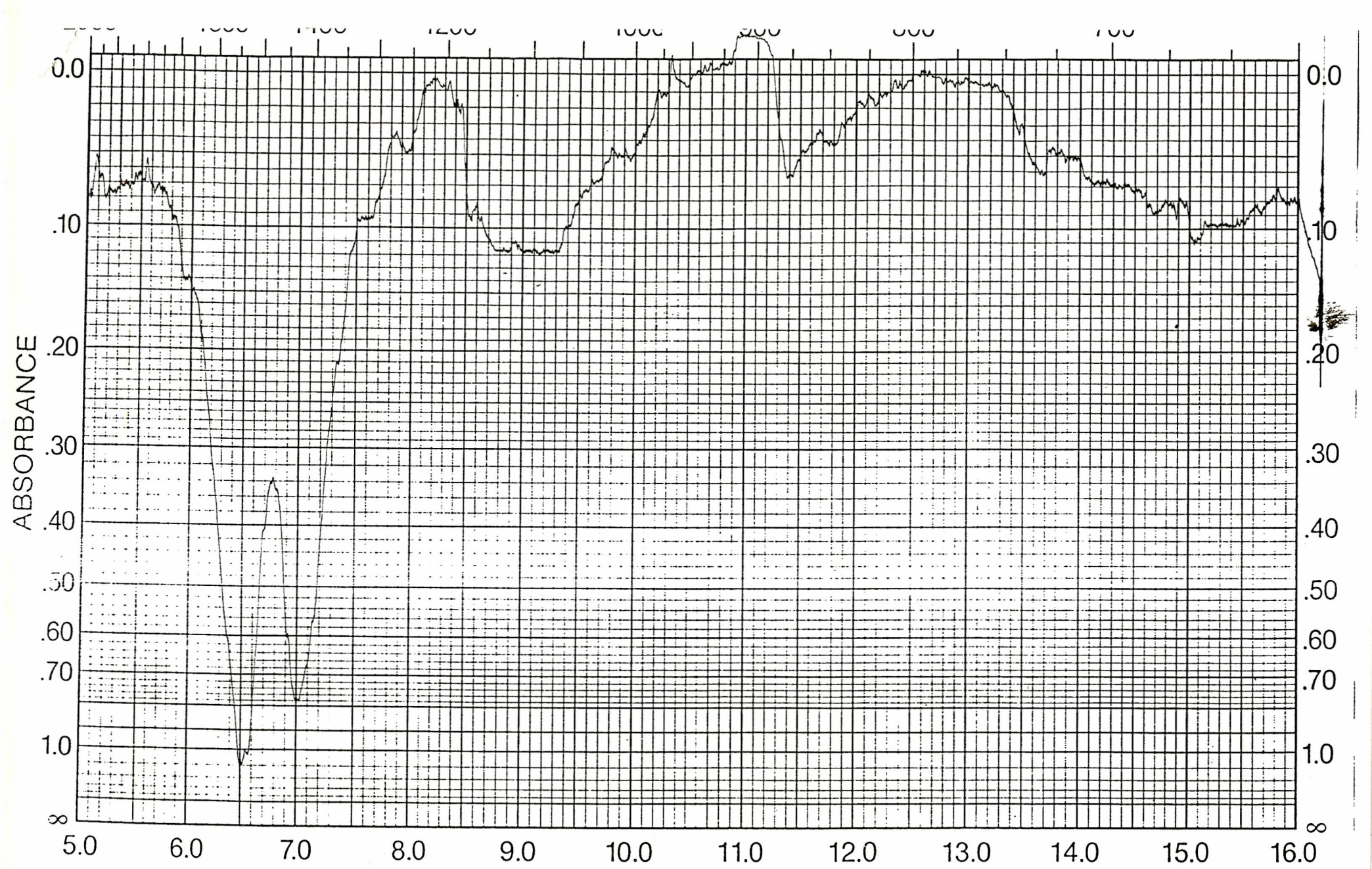

CHART NO. WGPE 237-1029

WILMAD GLASS CO., INC.
U.S. Route 40 and Oak Road
BUENA, N.J. 08310 U.S.A. Printed in U.S.A. 10-78/50/WP

SAMPLE gas filter	CURVE NO.	SCAN SPEED fast	OPERATOR
	CONC.	SLIT 6	DATE
ORIGIN	CELL PATH	REMARKS	

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7.46
6.46

OLD X

Exhaust Gas Analysis Form

Name of Company TRIANGLE

Date of Test MAY 20, 1987

Type of Equipment Tested

Engine Type and Specs 430 DET TURBO

Identification No. 115 Milage 481674

Type of Test

Ambient Air Temp.

Exhaust Readings

1.3 2.48

	CO	HC	CO_2	O_2	Exh. Temp.	RPM
1.	.01	18 13.7	1.96	18.2	316	1900
2.	.01	18 1.89	1.93	18.3 2.61	317	1900
3.	.01	18	1.85	18.6	314	1900
4.	.01	18	1.85	18.4	314	1900
5.	.01	17	1.87	18.9	312	1900
6.	.01	18	1.67	18.6	289	1600
7.	.01	18	1.69	18.6	286	1600
8.	.01	18	1.69	19.0	287	1600
9.	.01	17	1.70	18.6	286	1600
10.	.01	18	1.69	19.1	283	1600

50% .01 .01

Length of Test in minutes 10 MIN

Signature of Technicians

.16 .22

OLD X

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7:23
7:10

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test MAY 29 1987

Type of Equipment Tested

Engine Type and Specs 350 CUMMINS TURBO

Identification No. 117 Milage 90658

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.02	23	1.46	18.9	364	1900
2.	.02	23	1.47	18.9	368	1900
3.	.02	25	1.46	19.2	364	1900
4.	.02	25	1.46	18.9	363	1900
5.	.03	24	1.49	19.2	363	1900
6.	.02	23	1.28	19.3	337	1600
7.	.02	23	1.28	19.1	337	1600
8.	.02	24	1.29	19.5	335	1600
9.	.02	23	1.27	19.1	335	1600
10.	.02	23	1.27	19.5	333	1600

Length of Test in minutes 12 MIN

Signature of Technicians

Memorandum Report

To: Dave Zinn
Triangle Oil Company

From: Craig Flinders
UHI Corporation

Date: May 5, 1987

Subject: Analysis of Baseline Exhaust Gas Data

Accompanying this memorandum report find a, 1) computerized summary of the averages for the exhaust gas data recorded during the recent FPC-1 baseline test at your facility, 2) a graph of the percent CO2 in the exhaust stream (fuel flow) comparison for the three trucks (units 115, 101, 102) powered by Detroit 430 engines at 1600 and 1900 rpm, and 3) the formuli for the calculation of the engine performance factors.

Two comparisons will be made in this brief summary report. The first is a comparison of fuel flow to the engine as measured in percent CO2 at 1600 and 1900 rpm, respectively, for the three 430 powered units. These three trucks are used in this comparsion because the 430 engine is the most common in the fleet. The data is graphed and shows that fuel flow is substancially lower at 1600 rpm.

Although this comparison has no bearing on the outcome of the FPC-1 test, it does demonstrate that changes in fuel flow can be monitored using exhaust gas analysis. As you can see, the method is reliable as all major exhaust gases show changes that correspond with the reduction or increase in rpm and fuel flow.

The second comparison is done between the same three trucks at the same rpm and demonstrates which of the trucks is the more fuel efficient. The following table lists the trucks by unit number and makes the comparison at 1900 rpm. Again, fuel flow in terms of percent CO2 in critical to the comparison. Also included in the table are the engine performance factors calculated using the standard engineering formuli enclosed and the total molecular weight of the gases measured in the exhaust stream of each truck.

Comparison of 430 Detroit Engines at 1900 RPM

Unit #	%CO2	Molecular wt.	Performance factors
115	2.58	29.04	152,891.02
101	1.93	29.07	193,082.34
102	1.85	29.15	206,538.49

Based on the CO2 concentrations and the resultant engine performance factors, Unit 102 is the most efficient of the three 430 powered trucks. Unit 102 is 6.52% more fuel efficient than Unit 101 and 25.97% more efficient than Unit 115. If Unit 101 were averaging 5.0 miles per gallon, the following milages would be indicative of what I would expect to see in the other trucks based upon the CO2 in the exhaust stream:

Unit #	MPG
101	5.0
102	4.67 (-6.52% from 5.0)
115	3.70 (-25.97% from 5.0)

The pattern is similar for the same trucks at 1600 rpm.

Once again, this has little bearing on the outcome of the FPC-1 trial you are performing except that it gives greater credence to the exhaust gas analysis method of determining fuel flow changes to the engine.

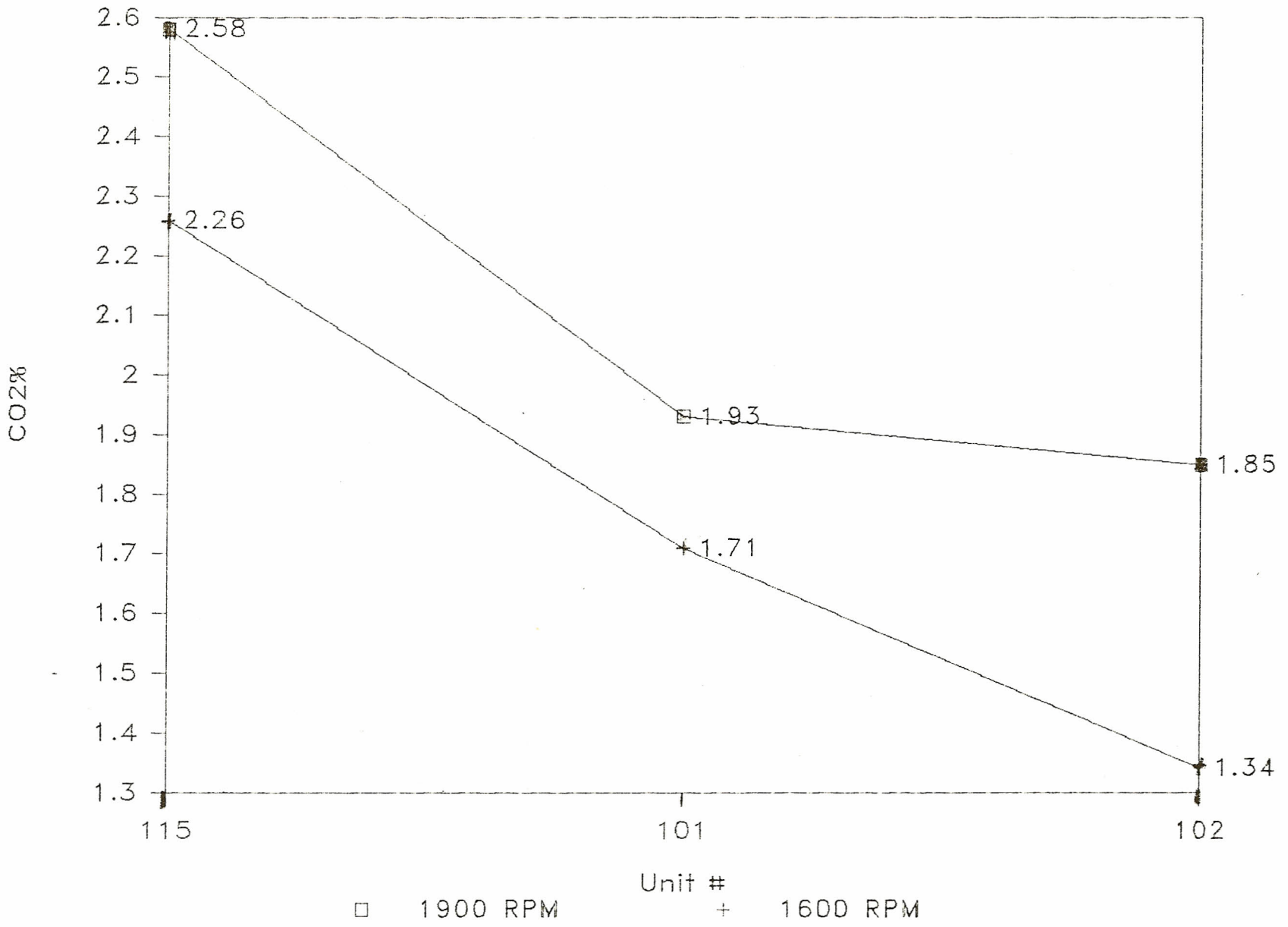
* Notes on Performance Factors:

1. Engine performance factors are calculated and use the total molecular weight of the exhaust gases (CO2, CO, HC, O2), the exhaust temperature, and the exhaust airflow rate data. The engine performance factor does not produce an absolute change in mileage since distance traveled is not determined in the exhaust gas test method. However, the method does provide a means of determining how efficiently the engine uses the fuel it receives and, therefore, engine performance factors can be used to determine comparative changes in fuel flow to the engine.

2. The higher the engine performance factor the more efficiently the engine is using the fuel. Once the performance factors are calculated, a simple subtraction and computation of the percent change will reveal the change in fuel flow to the engine. In most cases, the fuel flow change will correspond closely to the change in CO2.

3. The use of engine performance factors requires that baseline rpm and exhaust temperatures be reproduced in the FPC-1 treated fuel test segment. This will eliminate any variability in temperature and airflow.

Fuel Flow Comparison/430 Detroit



Triangle Oil Company 1900 RPM Data

Unit	Engine	CO2	HC	CO	O2	Temp.
115	430	2.58	21.2	0.02	18.04	310.2
101	430	1.93	22	0.014	18.92	269.6
102	430	1.85	17.8	0.02	18.52	291.4
117	350	1.91	29	0.028	18.72	354.6
112	350	2.42	21.6	0.024	18.04	354.6
114	400	1.71	28.2	0.03	19.1	355.6
116	400	2.15	22.2	0.03	18.72	366
30	673	2.8	35	0.046	17.74	352
486	673	3.22	33.8	0.03	17.22	439.2

Triangle Oil Company 1600 RPM Data

115	430	2.26	22	0.02	18.62	282.6
101	430	1.71	23	0.02	18.96	248.2
102	430	1.34	20.4	0.02	19.24	253.6
117	350	1.63	26	0.02	19.08	333.6
112	350	1.88	23.4	0.02	18.74	308.6
114	400	1.47	27	0.028	19.18	331.8
116	400	1.89	23.8	0.03	19.02	322
30	673	2.27	35.6	0.05	18.36	301
486	673	2.5	35	0.03	18.02	364.2

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Exhaust Gas Analysis Form

Name of Company _____

Date of Test _____

Type of Equipment Tested _____

Engine Type and Specs 673 285 H.P.

Identification No. V486 Milage 61794

Type of Test _____

Ambient Air Temp. _____

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	03	32	3.20	17.1	435	1900
2.	03	32	3.22	17.1	438	1900
3.	03	35	3.23	17.1	437	1900
4.	03	35	3.23	17.6	436	1900
5.	03	35	3.23	17.2	450	1900
6.	03	35	2.51	18.0	332	1600
7	03	35	2.50	18.1	373	1600
8	03	35	2.50	18.1	374	1600
9.	03	35	2.50	18.0	372	1600
10.	03	35	2.50	17.9	370	1600

Length of Test in minutes 10 min.

Signature of Technicians _____

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Exhaust Gas Analysis Form

Name of Company TRIANGLE OIL

Date of Test APRIL 16, 1987

Type of Equipment Tested

Engine Type and Specs MACK 673 T

Identification No. 30 Milage 176001

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	05	34	2.86	17.4	348	1900
2.	05	36	2.84	17.4	350	1900
3.	05	35	2.78	18.5	354	1900
4.	04	25	2.77	17.7	354	1900
5.	04	35	2.77	17.7	354	1900
6.	05	35	2.26	18.2	302	1600
7.	05	35	2.26	18.2	299	1600
8.	05	35	2.28	18.5	299	1600
9.	05	36	2.28	18.2	304	1600
10.	05	37	2.28	18.2	301	1600

Length of Test in minutes 11 mins.

Signature of Technicians

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417

RIGHT Side Exit

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test 4-17-87

Type of Equipment Tested

Engine Type and Specs 400 cum Turbo

Identification No. 116 Milage 240 490

Type of Test

Ambient Air Temp. 53

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	22	2.14	18.7	~~357~~ 368	1900
2.	.03	22	2.17	18.4	367	1900
3.	.03	22	2.15	19.0	366	1900
4.	.03	22	2.15	18.5	366	1900
5.	.03	23	2.14	19.0	363	1900
6.	.03	24	1.91	18.7	321	1600
7.	.03	24	1.89	18.7	319	1600
8.	.03	24	1.87	19.2	323	1600
9.	.03	23	1.90	18.8	324	1600
10.	.03	24	1.87	19.7	323	1600

Length of Test in minutes 9

Signature of Technicians

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803

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test 4-16-87

Type of Equipment Tested

Engine Type and Specs 400 CUMMINS TURBO

Identification No. 114 Milage 113792

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	28	1.71	19.5	355	1900
2.	.03	28	1.70	18.9	356	1900
3.	.03	28	1.72	19.4	356	1900
4.	.03	29	1.70	18.9	355	1900
5.	.03	28	1.72	18.8	357	1900
6.	.03	24	1.43	19.1	332	1600
7.	.03	27	1.42	19.1	332	1600
8.	.03	28	1.48	19.3	332	1600
9.	.02	28	1.51	19.1	332	1600
10.	.03	28	1.51	19.3	331	1600

Length of Test in minutes 9

Signature of Technicians

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Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test 4-16-87

Type of Equipment Tested

Engine Type and Specs 350 CUMMINS TURBO

Identification No. 112 Milage 027459

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	22	2.41	18.0	356	1900
2.	03	22	2.44	17.9	356	1900
3.	.02	21	2.40	18.2	353	1900
4.	02	21	2.42	18.1	351	1900
5.	02	22	2.42	18.0	357	1900
6.	02	24	1.89	18.7	310	~~1600~~ 1550
7.	02	24	1.89	18.7	309	~~1600~~ 1550
8.	02	24	1.89	18.7	309	~~1600~~ 1550
9.	02	22	1.87	18.9	308	~~1600~~ 1550
10.	02	23	1.87	18.7	307	~~1600~~ 1550

Length of Test in minutes 12 MINS

Signature of Technicians

12?

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Exhaust Gas Analysis Form

Name of Company TRIANGLE OIL

Date of Test APRIL 16, 1987

Type of Equipment Tested

Engine Type and Specs 350 cummins TURBO

Identification No. 117 Milage 83926

Type of Test

Ambient Air Temp. 47°

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.03	29	1.96	18.3	351	1900
2.	.02	31	1.90	18.4	353	1900
3.	.03	28	1.89	19.0	354	1900
4.	.03	29	1.89	18.7	357	1900
5.	.03	28	1.89	19.2	358	1900
6.	.02	26	1.64	19.0	332	1600
7.	.02	26	1.64	19.0	334	1600
8.	.02	26	1.63	19.4	335	1600
9.	.02	26	1.64	18.9	334	1600
10.	.02	26	1.64	19.1	333	1600

Length of Test in minutes 11 min

Signature of Technicians

cold

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917

Exhaust Gas Analysis Form

Name of Company TRIANGLE GAS

Date of Test 4-17-87

Type of Equipment Tested

Engine Type and Specs 440 DET. TURBO

Identification No. 102 Milage 49188

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.02	22	1.99	18.3	290	1900
2.	.02	24	2.04	18.3	291	1900
3.	~~.02~~ .02	~~15~~ 15	~~1.71~~ 1.74	~~19.0~~ 18.7	~~292~~ 293	1900
4.	.02	15	1.76	18.6	291	1900
5.	.02	13	1.71	18.7	292	1900
6.	.02	17	1.35	19.1	254	1600
7.	.02	18	1.33	19.1	253	1600
8.	.02	23	1.35	19.5	254	1600
9.	.02	23	1.35	19.1	253	1600
10.	.02	21	1.33	19.4	254	1600

Length of Test in minutes 9

Signature of Technicians

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729
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Exhaust Gas Analysis Form

Name of Company TRIANGLE OIL

Date of Test 4-16-87

Type of Equipment Tested

Engine Type and Specs 892 430 DET D TURBO

Identification No. 101 Milage 6138490 HUB

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.01	22	1.95	18.6	269	1900
2.	.01	22	1.94	18.6	270	1900
3.	.02	22	1.93	19.5	269	1900
4.	.02	22	1.93	18.7	269	1900
5.	.01	22	1.92	19.2	271	1900
6.	.02	22	1.71	18.8	250	1600
7.	.02	22	1.71	18.8	250	1600
8.	.02	24	1.70	18.9	248	1600
9.	.02	24	1.70	18.9	247	1600
10.	.02	23	1.71	19.4	246	1600

Length of Test in minutes 11

Signature of Technicians

RDP INC
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904
857
9084

Exhaust Gas Analysis Form

Name of Company TRIANGLE

Date of Test 4-17-87

Type of Equipment Tested

Engine Type and Specs 430 DET TURBO

Identification No. 115 Milage 474779

Type of Test

Ambient Air Temp.

Exhaust Readings

	CO	HC	CO_2	O2	Exh. Temp.	RPM
1.	.02	22	2.62	18.0	309	1900
2.	.02	24	2.61	17.9	311	1900
3.	.02	22	2.56	18.4	310	1900
4.	.02	19	2.56	18.0	311	1900
5.	.02	19	2.56	17.9	310	1900
6.	.02	22	2.29	18.4	281	1600
7.	.02	22	2.23	18.4	283	1600
8.	.02	22	230	18.9	285	1600
9.	.02	22	2.26	18.4	283	1600
10.	.02	22	2.24	19.0	281	1600

Length of Test in minutes 8

Signature of Technicians