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EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST

at

KENNECOTT, UTAH COPPER, BINGHAM CANYON MINE

Report Prepared by

UHI CORPORATION
PROVO, UTAH,

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I. INTRODUCTION

FPC-1 is a complex combustion catalyst which, when added to liquid petroleum base fuels, improves the combustion reaction. The primary result is an increase in engine efficiency and a reduction in fuel consumption. Secondary benefits include; 1) reduced engine smoking and harmful gaseous emissions, 2) reduced soot blow-by and related engine wear, and 3) reduced engine hard carbon buildup and related upper cylinder wear. Experience with diesel power mobile equipment indicates a potential to reduce fuel consumption by 6% to 9% with catalyst fuel treatment.

Kennecott, Utah Copper and UHI Corporation personnel jointly agreed to conduct a Carbon Mass Balance test on the mine haul trucks at the Bingham Canyon Mine in order to quantify the effect of FPC-1 fuel catalyst upon fuel consumption, exhaust smoke density and carbon monoxide emissions.

II. CONCLUSIONS

(1) After fuel treatment with FPC-1, fuel consumption was reduced in the Bingham Canyon Mine test fleet by 7.00% to 7.43%.

(2) Smoke density was reduced approximately 11% with FPC-1 fuel treatment.

(3) Carbon monoxide emissions were reduced approximately 11% with FPC-1 fuel treatment.

(4) The reduction in fuel consumption agrees with the experience of dozens of mining operators who have used FPC-1 for many years. Typical fuel consumption reductions average approximately 7.0% to 7.5% for operators using CAT 3500 series engines (see Customer Surveys).

III. RECOMMENDATIONS

Based upon the conclusions itemized above, it is the recommendation of UHI Corporation that Kennecott, Utah Copper begin treating all of it's fuel with FPC-1 as soon as possible. Assuming an average diesel fuel cost of $.70/gallon, fuel usage of 12,000,000 gallons/year, FPC-1 costs at $.023/gallon of treated fuel, and a savings of 7.4 3% on fuel consumption by treating with FPC-1, <u>Kennecott, Utah Copper will save $368,506 annually in fuel costs alone!</u>

IV. DISCUSSION OF TEST METHODS

Testing for fuel consumption determination in the field is difficult and time consuming. Although, it is comparatively easy to monitor gallons used or purchased and hours of engine operation or miles traveled, it is far more difficult to determine how fuel consumption is influenced by operating variables, such as load. Laboratory test procedures were developed for this very reason, to eliminate the uncontrolled operating variables affecting fuel consumption. UHI has solved the problem of collecting meaningful fuel consumption data by applying a heretofore laboratory method to field testing. The method uses a carbon mass balance calculation. The carbon mass balance method is central to the EPA standardized Federal Test Procedure (FTP) and Highway Fuel Economy Test (HFET), which have been used since 1974 as the basis for fuel economy labels under the EPA voluntary fuel economy labeling program (SAE Paper # 750002, B.H. Simpson, Ford Motor Co). It has proven to be at least as accurate for the determination of fuel consumption as volumetric and gravimetric methods (ibid).

Carbon Mass Balance

The carbon mass balance eliminates virtually all of the variables associated with field testing for fuel consumption changes. Under steady-state engine conditions, instead of measuring fuel flow into the engine (ie., the weight or volume of the fuel), measurements are made of the exhaust gases leaving the engine. More precisely, the carbon containing gases in the exhaust are measured.

The method is based upon the Law of Conservation of Matter, which states that atoms can neither be created nor destroyed, only changed in state, and that the weight or mass of the products of a reaction will be equal to the reactants themselves. Thus, the reactants and the products can be "balanced". Since the engine's only source of carbon is the fuel it consumes, the carbon measured in the exhaust must come from the fuel. By measuring the carbon going out of the engine in the form of products of combustion, the amount of carbon entering the engine can be determined.

Carbon Balance Calculation

The carbon leaving the engine is mainly in the form of carbon dioxide ($CO2$), carbon monoxide (CO), unburned hydrocarbons (HC), and particulate (smoke). By collecting these data while the engine is operating at a given load and speed (steady-state), the mass flowrate of the fuel into the engine can be accurately determined. When engine load and speed, along with other factors influencing fuel consumption (intake pressure and temperature, and fuel density) are reproduced and/or monitored to make appropriate corrections, the carbon balance can be used to confidently determine changes in fuel consumption that result from the use of FPC-1.

With the carbon balance, engine efficiency is expressed in terms of engine performance factors (PF). To calculate any change in engine performance, separate measurements are made with the engine running on baseline fuel (untreated) and FPC-1 treated fuel. Any changes are stated as percentage changes from baseline.

The engine performance factor or PF is a mass flowrate and relates to the length of time required to consume a volume of fuel. The higher the PF, the longer the time required to consume the same volume of fuel at a given load and engine speed. Therefore, an increase in PF equals a reduction in the rate of fuel consumption.

All fuel consumption and smoke density data were monitored and/or recorded by a Kennecott representative for Bingham Canyon. The exhaust gas data collected during the baseline and treated fuel carbon balance tests are summarized on the attached computer printouts found in Appendix 3.

From these data, the volume fraction (VF) of each gas was determined and the average molecular weight (Mwt) of the exhaust gases computed. Next, the engine performance factor (pf) or the carbon mass in the exhaust was computed. The pf is finally corrected for exhaust gas density and fuel density, yielding a engine performance factor (PF) or carbon mass flow rate corrected for total exhaust mass flow and fuel energy content.

The PFs are shown on the bottom of the computer printouts found in Appendix 1. The CMB calculations and legend are found on Figure 1 in Appendix 2. A sample calculation for illustration purposes is found on Figure 2, also in Appendix 2. The CMB equations were provided by Dr. Geoffrey J. Germane, PhD. Mechanical Engineering and Chairman of the Department of Mechanical Engineering for Brigham Young University. Dr. Germane's resume is attached in Appendix 3.

Additionally, the carbon balance can be used to determine the effect of FPC-1 upon harmful gaseous and particulate emissions, such as CO and smoke. The Bacharach Smoke Spot method is used to determine smoke density, while the NDIR analyzer measures carbon monoxide concentration.

Instrumentation

Precision, state-of-the-art instrumentation are used to measure the concentrations of carbon containing gases in the exhaust stream and other factors related to fuel consumption and engine performance. The instruments and their purposes are listed below:

1) A Sun Electric SGA-9000 non-dispersive infrared (NDIR) four gas analyzer - measures the volume percent of CO2, CO, and oxygen (O2) in the exhaust, and the parts per million (ppm) of HC.

2) EPA I/M Calibration Gases - approved calibration gases used to internally calibrate the NDIR analyzer.

3) A twenty (20) foot sampling train and stainless steel exhaust gas probe - inserted into the engine exhaust pipe draws a sample of exhaust gases to the analyzer.

4) A Fluke Model 52 hand held digital thermometer and wet/dry thermocouple probe - measures exhaust, ambient, and fuel temperature in degrees F.

5) A Dwyer Magnehelic 2000 Series Pressure Gauge and pitot tube - measures exhaust gas velocity and/or pressure differential.

6) A Monarch Contact/Noncontact digital tachometer and magnetic tape - measures engine rpm when dash mounted tachometers are unavailable.

7) A specific gravity hydrometer and flask - determines fuel specific gravity (density).

8) Barometric pressure is acquired from local airport or weather station.

9) A Bacharach Smokemeter and filter paper - determines smoke density.

With the exception of engine speed, fuel density, and ambient readings, all data are collected by simply inserting probes into the exhaust stream while the engine is running at a fixed rpm and load, thus eliminating variables created by load, weather, fuel quality changes, etc., over time. No modifications or device installation are made to the fuel system, nor are normal equipment work cycles disrupted.

Carbon Balance Technical Approach

The number of test engines and the quantity of data collected must be large enough to provide statistical confidence in the data and the results obtained. A minimum of five engines were tested to increase the size of the database, and improve the confidence level in the results obtained.

Also, all test engines were fuelled from the same location to facilitate controlled treatment with FPC-1, and minimum deviation in fuel quality.

Test instruments were calibrated by Kennecott and UHI engineers and technicians, and readings taken in a manner prescribed by all parties (ie, pitot tube placement, number of readings, etc.). The basic procedure for testing was as follows:

1) All instruments were calibrated according to accepted protocol. For each test run, the SGA-9000 was calibrated using the same bottle of BAR 90 calibration gases.

2) Before testing began, a sample of fuel was drawn from the fuel tank on each piece of equipment. Using a hydrometer and wet/dry temperature probe, fuel specific gravity and temperature were then recorded.

3) Engine hours or mileage were taken from hour meters and/or odometers.

4) Each engine was held at 1200 rpm while in reverse gear and stalled. A throttle lock was used to hold the engine rpm, preventing rpm swing.

5) During engine stabilization (measured as water temperature, exhaust gas temperature and pressure velocity), the exhaust gas sampling and temperature probes were inserted into the exhaust stream. However, no data were taken until stabilization had occurred. After stabilization, the Autocal button is depressed (as prescribed by Sun Electric) and, after the LED readouts cleared, test personnel took multiple readings of carbon dioxide (CO2), carbon monoxide (CO), unburned hydrocarbons (HC), oxygen (O2), and smoke, along with engine speed, exhaust temperature and pressure.

6) Periodically, intake air temperature and pressure (barometric) were recorded. Temperature readings were taken at the test site. Barometric pressure readings are acquired from local weather information services.

7) After taking exhaust gas data, smoke density readings were taken using the Bacharach Smokemeter.

8) All data were recorded until Kennecott and UHI testing personnel are satisfied that the information was consistent.

9) Back-to-back baseline Carbon Mass Balance tests were conducted to verify reproducibility.

10) After completing the baselines, the test engines were fuelled with FPC-1 treated fuel. The engines operated as normal for approximately 500 hours (approx. 21 days), at which time the above procedure were reproduced without alteration, except for FPC-1 fuel treatment.

Equipment Tested

Six CAT 793 haul trucks made up the original test fleet. One test truck had an engine replaced during the test period, therefore five trucks were tested with FPC-1 treated fuel.

Correction for Fuel Density

Dr. Germane's formula assumes a fuel density of 0.82 (specific gravity of diesel). UHI engineers measure actual fuel specific gravity by taking samples from the rolling tank on each truck. Only the treated rate of fuel consumption or PF2 is corrected for changes in fuel density (energy content). The baseline fuel density is used as the reference. The correction factor (if applicable) for fuel density is shown on the treated fuel database computer printouts. In this case, fuel density was greater for the treated tests. The energy content of the volume per unit volume of fuel injected into the engine would, therefore, be greater. Consequently, the mass flowrate or rate of fuel consumption for FPC-1 treated fuel must be corrected upward. In other words, the reduction in fuel consumption with FPC-1 fuel treatment is actually smaller than indicated by the exhaust gas readings.

Correction for Barometric Pressure

The barometric pressure is used in the calculation of both the baseline and treated fuel Pfs. These pressure readings were taken from the National Weather Service for the Northern Utah area. The weather data are found under Appendix 4. The barometric pressure readings are also shown on the aforementioned computer printouts.

Change in Exhaust Temperature

With the exception of Unit 254, exhaust gas temperature was higher during the FPC-1 treated fuel tests. This was primarily a result of longer running time during the treated fuel test. Technicians run the engines until baseline exhaust temperatures are reached, then data acquisition begins. This can lead to slightly longer running times. With longer the engine running time, (even after engine stabilization) in some cases, exhaust gas temperature will increase. This is a result of the metal in the exhaust system heating up, slowing the transfer of heat from the exhaust gases into metal pipes. Further, the air around the exhaust system also becomes heated, which also slows heat transfer from the hot gases.

The higher exhaust temperature was not a result of increased water or ambient temperature, as these were monitored, and were not changed from the baseline. RPM was also constant and reproduced.

If the baseline exhaust gas temperature were used in place of the treated exhaust temperature in carbon mass balance calculation, the reduction in fuel consumption is only slightly affected, averaging 7.0%, rather than 7.4%. Also, if the Carbon Mass Balance data were handled in this manner, Unit 254 would not be an anomaly, and could be included in the test sample.

V. DISCUSSION OF TEST RESULTS

Fuel Consumption

The back-to-back baselines verified the test procedure, and the condition of the engines attributed to reproducible test data. The two trucks in the test fleet that were available for back-to-back testing (Units 251 and 246) averaged a 2.68% change in fuel consumption between the two baselines (both units experienced increases in fuel consumption). The reading reproducibility for the SGA-9000 NDIR analyzer is 2% of full scale, therefore, the 2.68% change is close to the range of instrument error. The data and calculations for the back-to-back baselines on Units 251 and 246 are found in Appendix 5, Table 1.

Five trucks were tested on FPC-1 treated fuel after approximately 500 hours of engine preconditioning. The range of fuel consumption change for the five trucks was between -4.66% and -12.89%. Prior experience in the laboratory and field indicates the 12.89% reduction in fuel consumption is unlikely and therefore, it is considered an anomaly. With the anomaly removed from the sample, the average reduction in fuel consumption for the entire fleet is 7.43%.

The results of the fuel consumption calculations are summarized on Table 2 in Appendix 6. The raw data are summarized, and the carbon calculations are shown on the Computer Printouts of the database found in Appendix 1.

Smoke Density

Smoke is a product of incomplete combustion, and as such, is a measure of engine efficiency. Smoke is simply unburned fuel droplets not consumed during the final phase or tail of combustion when combustion temperatures are significantly lower, and most of the oxygen in the combustion chamber has been expended. The FPC-1 catalyst improves the oxidation of these fuel droplets, extracting more useful energy and reducing smoke emissions.

Smoke from the engines tested during the baseline and treated fuel tests was collected using the Bacharach Smokespot Method. The Bacharach method draws a specific volume of exhaust gas through a standard 5 micron filter medium. The particulate in the exhaust gas sample collects on the surface of the filter medium. The surface is darkened by the particulate according to the density of the particulate in the exhaust sample. The greater the particulate density, the darker the color. The Bacharach smoke scale ranges from 0 to 9, with 0 being a white, particulate free filter, and 9 being a black filter (anything off the scale is given a smoke number of 10).

The smoke spot numbers are relative smoke density numbers for each engine tested and can be used to determine any change in smoke emissions when compared to FPC-1 treated fuel. A comparison of the baseline and treated Smoke Numbers (shown on Table 3, Appendix 7) indicate the use of FPC-1 created an average reduction in smoke density of 11.1%.

Carbon Monoxide Concentration

Like smoke emissions, carbon monoxide (C0) concentrations in the exhaust are also a measure of engine efficiency. CO is produced in high concentrations early on during the diffusion type combustion typical to the compression-ignition engine. The complete oxidation of CO to CO2 releases significant amounts of energy. Reductions in CO indicate improved mixing of fuel with air, and improved rates of combustion.

In addition to reducing smoke, FPC-1 has long been known to reduce CO, when high concentrations are present in the combustion gases. For the most part, CO concentrations in the Kennecott fleet were not excessive, however, where CO emissions were high, CO concentrations were reduced. Overall reductions in CO concentration for the entire fleet after FPC-1 fuel treatment averaged 11.0% (similar to the smoke reduction). These data are tabulated on Table 4, Appendix 8.

APPENDIX 1

Company Name:	Kennecott	*Location*	Bingham Canyon	*Date:*	2/27/95
Test Portion:	Baseline #1	*Stack Diam.*	10 Inches		
Engine Type:	CAT 3516	*Mile/Hrs*	193021		
Equipment Type:	Haul Trucks	*ID #:*	241	*Baro*	30.03
Fuel Sp. Gravity(SG	.829	*Temp:*	76.4		
				Time:	

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	585	0.85	0.06	12	7.71	7.9	
1200	588	0.85	0.07	12	7.68	7.9	
1200	591	0.85	0.07	13	7.68	7.9	
1200	595	0.85	0.06	10	7.78	7.8	
1200	597	0.9	0.06	10	7.74	7.9	
1200	600	0.9	0.06	9	7.65	8.1	
1200	602	0.9	0.05	10	7.63	8.1	
1200	603	0.9	0.06	9	7.63	8.3	
1200	603	0.9	0.06	10	7.59	8.3	
1200	605	0.9	0.06	10	7.59	8.3	
1200	**596.900**	**.880**	**.061**	**10.500**	**7.668**	**8.050**	Mean
0	**6.951**	**.026**	**.006**	**1.354**	**.063**	**.196**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw1**	**pf1**	**PF1**
1.05E-05	0.00061	.077	.081	29.549	85,242	31,183

Company Name:	Kennecott	*Location:*	Bingham Canyon	*Test Date:*	4/10/95
Test Portion:	Treated	*Stack Diam:*	10 Inches		
Engine Type:	CAT 3516	*Mile/Hrs:*	202022		
Equipment Type	Haul Trucks	*ID #:*	241	*Baro:*	30.05
Fuel Sp. Gravity:	.834	*Temp:*	58.4		
SG Corr Factor:	.994			*Time:*	1110

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	632	0.85	0.05	9	7.06	9.5	
1200	638	0.85	0.05	8	7.03	9.6	
1200	645	0.85	0.05	9	7	9.6	
1200	647	0.85	0.05	9	7	9.7	
1200	652	0.85	0.05	10	6.95	9.7	
1200	658	0.9	0.05	10	6.92	9.7	
1200	661	0.9	0.05	11	6.99	9.6	
1200	664	0.85	0.05	10	6.9	9.7	
1200	666	0.9	0.05	10	6.9	9.7	
1200	669	0.9	0.05	10	6.9	9.7	
1200.000	**653.200**	**.870**	**.050**	**9.600**	**6.965**	**9.650**	Mean
0	**12.479**	**.026**	**.000**	**.843**	**.059**	**.071**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw2**	**pf2**	**PF2**
9.60E-06	0.0005	.070	.097	29.501	93,763	35,415

Performance factor adjusted for fuel density: 35,202

****% Change PF= 12.89 %**

***** A positive change in PF equates to a reduction in fuel consumption.***

Company Name:	Kennecott	*Location:*	Bingham Canyon	*Date:*	2/27/95
Test Portion:	Baseline #1	*Stack Diam.*	10 Inches		
Engine Type:	CAT 3516	*Mile/Hrs*	91790		
Equipment Type:	Haul Truck	*ID #:*	242	*Baro*	30.03
Fuel Sp. Gravity(SG	.830	*Temp:*	68.8		
				Time:	1015

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	661	0.9	0.02	10	7.16	9.4	
1200		0.9	0.02	10	7.16	9.4	
1200	657		0.02	12	7.06	9.5	
1200	663	0.9	0.03	10	7.43	9.6	
1200	674		0.03	10	7.54	9	
1200		0.9	0.04	10	7.6	8.9	
1200		0.9	0.04	10	7.71	8.7	
1200		0.9	0.04	10	7.59	8.8	
1200		0.9	0.04	10	7.79	8.7	
1200		0.9	0.04	10	7.59	8.8	
1200.000	**663.750**	**.900**	**.032**	**10.200**	**7.463**	**9.080**	Mean
0	**7.274**	**.000**	**.009**	**.632**	**.252**	**.355**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.02E-05	0.00032	.075	.091	29.558	87,928	32,797

Company Name:	Kennecott	*Location:*	Bingham Canyon	*Test Date:*	4/10/95
Test Portion:	Treated	*Stack Diam:*	10 Inches		
Engine Type:	CAT 3516	*Mile/Hrs:*	198926		
Equipment Type	Haul Truck	*ID #:*	242	*Baro:*	30.04
Fuel Sp. Gravity:	.839	*Temp:*	59.4		
SG Corr Factor:	.989			*Time:*	

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	690	1	0.03	12	6.62	9.8	
1200	697	1	0.03	17	6.48	9.6	
1200	702	1	0.03	17	6.42	9.7	
1200	703	1.1	0.03	15	6.44	9.5	
1200	705	1.1	0.03	14	6.5	9.6	
1200	710	1.1	0.03	10	6.48	9.6	
1200	716	1	0.02	10	6.45	9.7	
1200	720	1	0.02	10	6.48	9.7	
1200	722	1	0.02	10	6.44	9.8	
1200.000	**707.222**	**1.033**	**.027**	**12.778**	**6.479**	**9.667**	Mean
0	**10.710**	**.050**	**.005**	**3.032**	**.059**	**.100**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
1.28E-05	0.000266667	.065	.097	29.424	100,803	35,768

Performance factor adjusted for fuel density: 35,380

****% Change PF= 7.88 %**

***** A positive change in PF equates to a reduction in fuel consumption.***

Company Name:	Kennecott	*Location:*	Bingham Canyon	*Date:*	2/27/95
Test Portion:	Baseline #1	*Stack Diam.*	10 Inches		
Engine Type:	CAT 3612	*Mile/Hrs*	84554		
Equipment Type:	Haul Truck	*ID #:*	246	*Baro*	30.07
Fuel Sp. Gravity(SG	.829	*Temp:*	64		
				Time:	1435

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	698	0.7	0.04	10	6.96	8.8	
1200	703	0.75	0.05	10	6.96	8.8	
1200	708	0.75	0.05	10	6.94	8.8	
1200	713	0.8	0.05	10	6.96	8.8	
1200	716	0.8	0.05	10	6.99	8.8	
1200	722	0.75	0.05	10	6.97	8.9	
1200	726	0.8	0.05	10	7	8.9	
1200	729	0.8	0.05	10	7.01	8.9	
1200	733	0.8	0.05	10	7.01	8.9	
1200	734	0.8	0.05	11	7.05	8.8	
1200.000	**718.200**	**.775**	**.049**	**10.100**	**6.985**	**8.840**	Mean
0	**12.630**	**.035**	**.003**	**.316**	**.033**	**.052**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.01E-05	0.00049	.070	.088	29.472	93,413	38,472

Company Name:	Kennecott	*Location:*	Bingham Canyon	*Test Date:*	4/11/95
Test Portion:	Treated	*Stack Diam:*	10 Inches		
Engine Type:	CAT 3612	*Mile/Hrs:*			
Equipment Type	Haul Truck	*ID #:*	246	*Baro:*	30.09
Fuel Sp. Gravity:	.837	*Temp:*	64.2		
SG Corr Factor:	.990			*Time:*	1100

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	726	0.75	0.05	6	6.74	10.4	
1200	735	0.75	0.05	6	6.77	10.3	
1200	730	0.75	0.05	6	6.78	10.3	
1200	740	0.75	0.06	6	6.77	10.3	
1200	740	0.75	0.05	8	6.79	10.3	
1200	739	0.75	0.05	9	6.8	10.3	
1200	738	0.75	0.06	9	6.77	10.2	
1200	741	0.75	0.05	9	6.8	10.2	
1200	745	0.75	0.05	9	6.79	10.2	
1200	750		0.06	9	6.79	10.2	
1200.000	**738.400**	**.750**	**.053**	**7.700**	**6.780**	**10.270**	Mean
0	**6.883**	**.000**	**.005**	**1.494**	**.018**	**.067**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
7.70E-06	0.00053	.068	.103	29.496	96,259	40,657

Performance factor adjusted for fuel density: 40,265

****% Change PF= 4.66 %**

***** A positive change in PF equates to a reduction in fuel consumption.***

Company Name:	Kennecott	*Location*	Bingham Canyon	*Date:*	2/27/95
Test Portion:	Baseline #1	*Stack Diam.*	10 Inches		
Engine Type:	CAT 3516	*Mile/Hrs*	47694		
Equipment Type:	Haul Truck	*ID #:*	251	*Baro*	30.09
Fuel Sp. Gravity(SG	.830	*Temp:*	65	*Time:*	

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	697	0.95	0.04	9	7.22	9.5	
1200	702	1	0.04	10	7.27	9.4	
1200	706	0.95	0.04	11	7.3	9.4	
1200	715	0.95	0.05	12	7.26	9.4	
1200	719	0.95	0.05	12	7.29	9.4	
1200	715	0.95	0.04	12	7.54	9	
1200	724	0.95	0.05	10	7.28	9.5	
1200	727	0.95	0.06	10	7.54	9.1	
1200	738	0.95	0.05	12	7.26	9.4	
1200	745	0.95	0.05	12	7.35	9.3	
1200.000	**718.800**	**.955**	**.047**	**11.000**	**7.331**	**9.340**	Mean
0	**15.274**	**.016**	**.007**	**1.155**	**.115**	**.165**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.10E-05	0.00047	.073	.093	29.547	89,283	33,144

Company Name:	Kennecott	*Location:*	Bingham Canyon	*Test Date:*	4/11/95
Test Portion:	Treated	*Stack Diam:*	10 Inches		
Engine Type:	CAT 3516	*Mile/Hrs:*	125365		
Equipment Type	Haul Truck	*ID #:*	251	*Baro:*	30.08
Fuel Sp. Gravity:	.836	*Temp:*	66.8		
SG Corr Factor:	.993			*Time:*	930

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	753	0.85	0.07	6	7.3	10.2	
1200	757	0.85	0.06	7	7.32	10.2	
1200	757	0.85	0.06	6	7.32	10.2	
1200	758	0.85	0.07	6	7.29	10.2	
1200	761	0.8	0.06	6	7.28	10.2	
1200	763	0.8	0.07	6	7.32	10.1	
1200	764	0.85	0.06	6	7.35	10.1	
1200	769	0.85	0.07	6	7.31	10.1	
1200	769	0.85	0.07	6	7.3	10.1	
1200	768	0.85	0.07	8	7.28	10.1	
1200	768	0.85	0.07	6	7.21	10.2	
1200	767	0.8	0.07	6	7.22	10.1	
1200	767	0.85	0.07	6	7.2	10.1	
1200	768	0.85	0.07	7	7.21	10.2	
1200.000	**763.500**	**.839**	**.067**	**6.286**	**7.279**	**10.150**	Mean
0	**5.389**	**.021**	**.005**	**.611**	**.049**	**.052**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.29E-06	0.000671429	..073	.102	29.571	89,775	36,212

Performance factor adjusted for fuel density: 35,950

****% Change PF= 8.47 %**

***** A positive change in PF equates to a reduction in fuel consumption.***

Company Name:	Kennecott	*Location*	Bingham Canyon	*Date:*	2/27/95
Test Portion:	Baseline #1	*Stack Diam.*	10 Inches		
Engine Type:	CAT 3516	*Mile/Hrs*	53071		
Equipment Type:	Haul Truck	*ID #:*	254	*Baro*	30.05
Fuel Sp. Gravity(SG	.829	*Temp:*		*Time:*	

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	716	0.5	0.09	9	7.75	8.5	
1200	721	0.55	0.09	9	7.74	8.6	
1200	726	0.55	0.09	9	7.78	8.6	
1200	731	0.5	0.09	8	7.79	8.6	
1200	736	0.55	0.09	6	7.83	8.6	
1200	737	0.55	0.08	5	7.74	8.6	
1200	737	0.6	0.08	5	7.67	8.8	
1200	740	0.55	0.08	6	7.73	8.7	
1200	744	0.55	0.08	5	7.65	8.9	
1200	745	0.55	0.08	5	7.68	8.9	
1200.000	**733.300**	**.545**	**.085**	**6.700**	**7.736**	**8.680**	Mean
0	**9.661**	**.028**	**.005**	**1.829**	**.057**	**.140**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
6.70E-06	0.00085	.077	.087	29.585	84,368	41,686

Company Name:	Kennecott	*Location:*	Bingham Canyon	*Test Date:*	4/11/95
Test Portion:	Treated	*Stack Diam:*	10 Inches		
Engine Type:	CAT 3516	*Mile/Hrs:*	53892		
Equipment Type	Haul Truck	*ID #:*	254	*Baro:*	30.07
Fuel Sp. Gravity:	.831	*Temp:*	69		
SG Corr Factor:	.998			*Time:*	1305

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
1200	711	0.55	0.05	17	6.92	9.3	
1200	713	0.55	0.05	17	6.92	9.2	
1200	716	0.55	0.05	17	6.9	9.3	
1200	717	0.55	0.05	19	6.92	9.3	
1200	718	0.55	0.05	19	6.92	9.3	
1200	719	0.55	0.05	19	6.92	9.2	
1200	722	0.6	0.05	18	6.92	9.3	
1200	723	0.6	0.05	18	6.92	9.3	
1200	725	0.6	0.05	19	6.94	9.3	
1200	727	0.55	0.05	23	6.99	9.3	
1200.000	**719.100**	**.565**	**.050**	**18.600**	**6.927**	**9.280**	Mean
0	**5.152**	**.024**	**.000**	**1.776**	**.024**	**.042**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
1.86E-05	0.0005	.069	.093	29.481	94,130	45,421

Performance factor adjusted for fuel density: 45,312

****% Change PF= 8.70** %

***** A positive change in PF equates to a reduction in fuel consumption.***

APPENDIX 2

Figure 1
CARBON MASS BALANCE FORMULAE

ASSUMPTIONS: $C_{12}H_{26}$ and SG = 0.82
Time is constant
Load is constant

DATA:

Mwt = Molecular Weight
pf1 = Calculated Performance Factor (Baseline)
pf2 = Calculated Performance Factor (Treated)
PF1 = Performance Factor (adjusted for Baseline exhaust mass)
PF2 = Performance Factor (adjusted for Treated exhaust mass)
CFM = Volumetric Flow Rate of the Exhaust
SG = Specific Gravity of the Fuel
VF = Volume Fraction
d = Exhaust stack diameter in inches
Pv = Velocity pressure in inches of H_20
P_B = Barometric pressure in inches of mercury
Te = Exhaust temperature ^{O}F

VFHC = "reading" ÷ 1,000,000
VFCO = "reading" ÷ 100
$VFCO_2$ = "reading" ÷ 100
VFO_2 = "reading" ÷ 100

EQUATIONS:

Mwt =

$$(VFHC)(86)+(VFCO)(28)+(VFCO_2)(44)+(VFO_2)(32)+[(1-VFHC-VFCO-VFCO_2-VFO_2)(28)]$$

pf1 or pf2 =

$$\frac{3099.6 \times Mwt}{86(VFHC)+13.89(VFCO)+13.89(VFCO_2)}$$

CFM =

$$\frac{(d/2)^2\pi}{144}\left(1096.2\sqrt{\frac{Pv}{1.325(PB/ET+460)}}\right)$$

PF1 or PF2 =

$$\frac{pf \times (Te+460)}{CFM}$$

FUEL ECONOMY:
PERCENT INCREASE (OR DECREASE)

$$\frac{PF2 - PF1}{PF1} \times 100$$

Figure 2.

SAMPLE CALCULATION FOR THE CARBON MASS BALANCE

BASELINE:

Equation 1 (Volume Fractions)

VFHC = 13.20/1,000,000
= 0.0000132

VFCO = 0.017/100
= 0.00017

$VFCO_2$ = 1.937/100
= 0.01937

VFO_2 = 17.10/100
= 0.171

Equation 2 (Molecular Weight)

$$Mwt1 = (0.0000132)(86)+(0.00017)(28)+(0.01937)(44)+(0.171)(32) + [(1-0.0000132-0.00017-0.01937-0.171)(28)]$$

$$Mwt1 = 28.995$$

Equation 3 (Calculated Performance Factor)

$$pf1 = \frac{3099.6 \times 28.995}{86(0.0000132)+13.89(0.00017)+13.89(0.01937)}$$

$$pf1 = 329{,}809$$

Equation 4 (CFM Calculations)

$$CFM = \frac{(d/2)^2 \pi}{144} \left(1096.2 \sqrt{\frac{Pv}{1.325(PB/ET+460)}} \right)$$

d =Exhaust stack diameter in inches
Pv =Velocity pressure in inches of H_20
P_B =Barometric pressure in inches of mercury
Te =Exhaust temperature ^OF

$$CFM = \frac{(10/2)^2 \pi}{144} \left(1096.2 \sqrt{\frac{.80}{1.325(30.00/313.100+460)}} \right)$$

CFM =2358.37

Equation 5 (Corrected Performance Factor)

$$PF1 = \frac{329{,}809(313.1 \text{ deg F} + 460)}{2358.37 \text{ CFM}}$$

PF1 = 108,115

TREATED:

Equation 1 (Volume Fractions)

VFHC = 14.6/1,000,000
= 0.0000146

VFCO = .013/100
= 0.00013

$VFCO_2$ = 1.826/100
= 0.01826

VFO_2 = 17.17/100
= 0.1717

Equation 2 (Molecular Weight)

Mwt2 $=(0.0000146)(86)+(0.00013)(28)+(0.01826)(44)+(0.1717)(32) + [(1-0.0000146-0.00013-0.01826-0.1717)(28)]$

Mwt2 $= 28.980$

Equation 3 (Calculated Performance Factor)

$$pf2 = \frac{3099.6 \times 28.980}{86(0.0000146)+13.89(0.00013)+13.89(0.01826)}$$

pf2 $= 349{,}927$

Equation 4 (CFM Calculations)

$$CFM = \frac{(d/2)^2\pi}{144}\left(1096.2\sqrt{\frac{Pv}{1.325(PB/ET+460)}}\right)$$

d =Exhaust stack diameter in inches
Pv =Velocity pressure in inches of H_20
P_B =Barometric pressure in inches of mercury
Te =Exhaust temperature ^OF

$$CFM = \frac{(10/2)^2\pi}{144}\left(1096.2\sqrt{\frac{.775}{1.325(29.86/309.02+460)}}\right)$$

CFM $= 2320.51$

Equation 5 (Corrected Performance Factor)

$$PF2 = \frac{349{,}927(309.02 \text{ deg F} + 460)}{2320.51 \text{ CFM}}$$

$= 115{,}966$

Fuel Specific Gravity Correction Factor

Baseline Fuel Specific Gravity - Treated Fuel Specific Gravity/Baseline Fuel Specific Gravity +1

.840-.837/.840+1=1.0036

PF2 = 115,966 x Specific Gravity Correction

PF2 = 115,966 x 1.0036

PF2 = 116,384

Equation 6 (Percent Change in Engine Performance Factor:)

$$\% \text{ Change PF} = \frac{\text{PF2 - PF1}}{\text{PF1}} \times 100$$

% Change PF = [(116,384 - 108,115)/108,115](100)

= +7.65

Note: A positive change in PF equates to a reduction in fuel consumption.

APPENDIX 3

Abbreviated Resume -- December 1994

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Germane Engineering
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Professor and Chair, Department of Mechanical Engineering
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Brigham Young University
Provo, Utah 84602
(801) 378-6536

Born July 3, 1950 in Cleveland, Ohio; U.S. Citizen; Married

Appointments at Brigham Young University

Assistant Professor of Mechanical Engineering, September 1979
Associate Professor of Mechanical Engineering, September 1984
Professor of Mechanical Engineering, 1993
Chair, Department of Mechanical Engineering, BYU, August 1991 - present

Education

High School - Mayfield High School, Mayfield Village, Ohio, 1968.
B.S. Mechanical Engineering - Rose-Hulman Institute of Technology, May, 1972.
M.S. Mechanical Engineering - Rose-Hulman Institute of Technology, May, 1975.
Ph.D. Mechanical Engineering - Brigham Young University, Apr., 1979.

Honorary and Professional Society Memberships

The Society of Sigma XI
Society of Automotive Engineers
Pi Tau Sigma
Phi Kappa Phi
American Society for Engineering Education

Honors and Awards

- Pi Tau Sigma, National Mechanical Engineering Honorary
- Elected to Phi Kappa Phi, 1977
- Elected to Sigma Xi, 1979
- BYU Sigma Xi Engineering Dissertation of the Year ,1978
- Society of Automotive Engineers Teetor Award for Engineering Educators, 1981
- Outstanding Young Men of America, 1981
- Esquire Registry, "The Best of the New Generation," December, 1984
- Outstanding Teacher, Mechanical Engineering Department, 1985-86
- Outstanding Teacher, Mechanical Engineering Department, 1988-89

Related Experience and Employment

- Consultant to numerous law firms (motor vehicle accident reconstruction; automotive crash analysis and safety; industrial, power plant accident reconstruction; and mechanical design analysis), 1981 - present
- Consultant, Collision Safety Engineering, Orem, Utah (automotive crash analysis and safety; motor vehicle accident reconstruction and design analyses; safety research), 1980 - 1991
- Board of Scientists, SEMA Foundation (automotive equipment safety specifications), 1980 - 1984
- Technical Advisory Committee, SFI Foundation (motor vehicle aftermarket and racing equipment safety specifications), 1989 - present
- Consultant, National Hot Rod Association (fuels certification supervision and safety), 1973 - present
- Consultant, UHI corporation (manufacturing, supervision of product evaluation and technical personnel), 1980 - present
- Consultant, SNOWMOCROSS (engineering design), 1984
- Consultant, Health Care Group (medical products), 1981 - 1984
- Consultant, Deseret Professional (general engineering development), 1979 - 1985
- Member, Utah Legislative Committee on Alternate Fuels, 1979
- Research advisor to Collision Safety Engineering Bio-headform project, 1985-1991
- Consultant, Utah Power and Light Co., 1980 - 1985
- Consultant, Carvern Petrochemical (fuel additives), 1980 - 1985
- Consultant, Hercules, Inc. (fuels evaluation supervision), 1979 - 1980
- Consultant, Public Service of New Mexico (Coal Pulverizer inerting systems), 1980
- Consultant, H.C. Sleigh, Melbourne, Australia (fuel additives evaluation procedures), 1980

•Consultant, Biomass Inc. (alcohol fuels), 1980
•Consultant, Angus Chemical Co., Nitromethane combustion in engines, at BYU, 1983 - 1987
•Member, Utah State Tax Recodification Task Force, member of task committee, 1988
•Member, Utah Legislative Committee on Alternate Fuels, 1979

Publications

1. Germane, G.J., "The Effect of Acetic Acid Upon the Antiknock Properties of Methylcyclopentadienyl Manganese Tricarbonyl in Hydrocarbon Fuels," M.S. Thesis, Rose-Hulman Institute of Technology, Terre Haute, IN, December, 1974.

2. Germane, G.J., "Computer Controlled Dynamic Tests with Motoring of an Internal combustion Engine with Alternate Fuels," Ph.D. Dissertation, Brigham Young University, Provo, UT, December 1978.

3. Germane, G.J., Free, J.C., and Heaton, H.S., "General Nonlinear Dynamic Characterization of an Internal Combustion Engine Electrical Dynamometer System," Proceedings of the Tenth Annual Pittsburgh Conference, Instrument Society of America, Pittsburgh, PA, March, 1979.

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5. Smoot, L.D., Germane, G.J., Cannon, J.N., and Trost, L.C., "Pulverized Coal Power Plant Fires and Explosions," Summary Report Part I, Utah Power and Light Co., Salt Lake City, UT, September, 1979.

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7. Germane, G.J., Smoot, L.D., Cannon, J.N., and Trost, L.C., "Pulverized Coal Power Plant Fires and Explosions," Summary Report Part II, Utah Power and Light Co., Salt Lake City, UT, January, 1980.

8. Germane, G.J., and Heaton, H.S., "The Effect of Alcohol Fuels Under Dynamic Operating Conditions on Engine Efficiency and Emissions," Fourth International Symposium on Alcohol Fuels Technology, Sao Paulo, Brazil, October, 1980.

9. Germane, G.J., Smoot, L.D., Cannon, J.N., Cutler, R.P., and Schramm, D.E., "Pulverized Coal Power Plant Fires and Explosions," Summary Report Part III, Utah Power and Light Co., Salt Lake City, UT, April, 1981.

10. Cannon, J.N., Germane, G.J., Cutler, R.P. Schramm, D.E., Carr, D.G., and Smoot, L.D., "Pulverized Coal Power Plant Fires and Explosions," Summary Report Part IV, Utah Power and Light Co., Salt Lake City, UT, April, 1981.

11. Germane, G.J., et.al., "Coal-Water Mixture Combustion Studies in a Laboratory Cylindrical Combustor," Proceedings of the Fourth International Symposium on Coal Slurry Combustion, Orlando, FL, May, 1982.

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13. Cannon, J.N., Germane, G.J., Smoot, L.D., Nye, C.N., and Spackman, H.M., "Pulverized Coal Power Plant Fires and Explosions," Summary Report Part VI, Utah Power and Light Co., Salt Lake City, UT, May, 1982.

14. Germane, G.J., et.al., "Reduction in Oil Use in Coal-Fired Utility Boilers," Summary Report Part VII, Utah Power and Light Co., Salt Lake City, UT, August, 1982.

15. Parsons, J.B. and Germane, G.J., "Effect of an Iron-Based Combustion Catalyst on Diesel Fleet Operation," SAE Paper 831204, West Coast International Meeting, Vancouver, B.C., August, 1982. SAE Special Publication SP-548, Fuel Alternatives for Spark Ignition and Diesel Engines.

16. Warner, C.Y., Smith, C.C., James, M.J. and Germane, G.J., "Friction Applications in Automobile Accident Reconstruction," SAE Paper 830612, Society of Automotive Engineers International Congress and Exposition, Detroit, MI, February, 1983.

17. Germane, G.J., "Automotive Racing Fuels - A Technical Analysis and Review," SAE West Coast International Meeting, Vancouver, B.C., August, 1983.

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Patents

1. "Nitromethane Fuel Compositions," U. S. Patent 4,583,991 granted to Geoff J. Germane and Gary L. Hess, 1986.

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APPENDIX 4

Figure 3. Barometric Pressure Readings from Provo, Utah Area

Date	Time	Baro
2-27-95	9:00	30.03
	10:00	30.03
	12:00	30.09
	13:00	30.07
3-15-95	8:00	30.10
	9:00	30.13
	10:00	30.13
	11:00	30.13
	12:00	30.12
	13:00	30.09
	14:00	30.07
	15:00	30.05
4-10-95	8:00	30.03
	9:00	30.03
	10:00	30.04
	11:00	30.05
	12:00	30.04
4-11-95	9:00	30.08
	10:00	30.08
	11:00	30.09
	12:00	30.08
	13:00	30.07
	14:00	30.05

APPENDIX 5

Table 1. Bingham Canyon Test Fleet Baseline PFs (mass flow rates)

Unit No.	Baseline 1 PF	Baseline 2 PF	% Chg
251	33,144	32,517	- 2.19
246	38,472	37,265	- 3.17
Ave. Chg for Trucks Tested:			- 2.68

Note 1: A decrease (-) in PF indicates an increase in fuel consumption.

Note 2: The 2.68% increase in fuel consumption between the two baseline tests for the same units is not significant given the accuracy of the NDIR instrument ($\pm$2% of full scale reproducibility) and indicates that the baselines were reproduced only.

APPENDIX 6

Table 2: Comparison of Rates of Fuel Consumption (Engine Performance Factors)

Unit No.	Baseline PF	Treated *PF	%Change
251	33,144	35,950	+8.47
254	41,686	45,312	+8.70
246	38,472	40,265	+4.66
242	32,797	35,768	+7.88
**241	31,183	35,415	+12.89

* PF is an abbreviation for "Performance Factor". The Performance Factor is a mass flowrate that is related to the length of time required to consume a given volume of fuel. The larger the PF, the longer the time required to consume a given volume of fuel at the same engine load, therefore, a positive change in PF equates to a reduction in fuel consumption.

** Statistical anomaly not included in the fleet average.

The fuel consumption reductions shown in Table 2 (average 7.43%) have been corrected for the effects of intake air pressure (barometric) and temperature (ambient), and fuel density (measured as specific gravity).

Unit 250 is not included in the test fleet due to an engine replacement. In fact, the engine was being replaced during the treated fuel test period (April 10 and 11).

APPENDIX 7

Table 3: Comparison of Smoke Spot Numbers (Changes in Smoke Density)

Unit No.	Baseline SS#	Treated *SS#	% Change
251	8.0	8.0	0.0
254	10.0	7.0	30.0
246	7.5	7.0	6.7
242	7.5	7.0	6.7
241	7.5	7.0	6.7
Fleet avg. smoke readings & reduction:	8.1	7.2	11.1

* SS# is the abbreviation for Smokespot Number. The Smokespot Number is a measure of relative smoke density using the Bacharach Smokespot scale and test method. The higher the SS#, the greater the smoke density.

APPENDIX 8

Table 4: Comparison of Carbon Monoxide Emissions

	Unit No.	Baseline C0%	Treated CO%	%Change
	251	0.085	0.050	-41.18
	254	0.047	0.067	+42.55
	246	0.049	0.053	+ 8.16
	242	0.032	0.027	-15.62
	241	0.061	0.050	-18.03
Fleet Average:		0.055	0.049	-10.99

RAW DATA WORK SHEETS

Carbon Mass Balance Field Data Form

Company: [illegible] Location: [illegible] Test Date: [illegible]

Treated: Exhaust Stack Diameter: [illegible] Inches

Type of Equipment: ___

Fuel Specific Gravity: ________ @:________ (°F)

Barometric Pressure: ________ Inches of Mercury

Intake Air Temperature: 30.03 (°F) Start Time:________

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1700	585	0.85	.06	12	7.71	7.9	
	588	0.85	.07	12	7.68	7.9	
	591	0.85	.07	13	7.68	7.9	
	595	0.85	.06	10	7.78	7.8	
	597	0.9	.06	10	7.74	7.9	
	600	0.9	.06	9	7.65	8.1	
	602	0.9	.05	10	7.63	8.1	
	603	0.9	.06	9	7.63	8.3	
	603	0.9	.06	10	7.59	8.3	
	605	0.9	.06	10	7.59	8.3	

Throttle lock ✓ Smoke # 7.5

End Time________

Names of Customer Personnel Participating in Test:

________ ________

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Test Date: 2/27/95
Test Portion: Baseline: X Treated: ______ Exhaust Stack Diameter: 10 Inches

Engine Make/Model: Cat 3516 Miles/Hours: 91790 I.D.#: 242
Type of Equipment: 240 T Haul Truck

Fuel Specific Gravity: .830 @: 68.0 (°F)
Barometric Pressure: 30.03 Inches of Mercury
Intake Air Temperature: 65°F (°F) Start Time: 10:[illegible] AM

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	661	.9	.02	10	7.16	9.4	
		.9	.02	10	7.16	9.4	
	657		.02	12	7.06	9.5	
	663	.9	.03	10	7.43	9.6	
	674		.03	10	7.54	9.0	
	415	.9	.04	10	7.60	8.9	
	396	.9	.04	10	7.71	8.7	
	411	.9	.04	10	7.59	8.8	
	413	.9	.04	10	7.79	8.7	
	411	.9	.04	10	7.59	8.8	

Handwritten notes: Rounds stalled; Compressor on; Short on thermocouple wire; Repaired thermocouple; Bottom Dead; Smoke # 7.5

663.7 .9 7.467

End Time________

Names of Customer Personnel Participating in Test:

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Test Date: 2/17/93
Test Portion: Baseline: X Treated: Exhaust Stack Diameter: 10 Inches

Engine Make/Model: CAT 3612 Miles/Hours: 84554 I.D.#: 246
Type of Equipment: 240 T Haul Truck

Fuel Specific Gravity: ______ @: 64 (°F)
Barometric Pressure: 30.07 Inches of Mercury
Intake Air Temperature: ______ (°F) Start Time: 2:35 pm

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	698	.70	.04	10	6.96	8.8	
↓	703	.75	.05	10	6.96	8.8	
	708	.75	.05	10	6.94	8.8	
	713	.8	.05	10	6.96	8.8	
	716	.8	.05	10	6.99	8.8	
	722	.75	.05	10	6.97	8.9	
	724	.8	.05	10	7.00	8.9	
	729	.8	.05	10	7.01	8.9	
	733	.8	.05	10	7.01	8.9	
	734	.8	.05	10	7.05	8.8	

Smoke #7.5

End Time ______

Names of Customer Personnel Participating in Test:

______ ______

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Test Date: 2/12/93
Test Portion: Baseline: ✓ Treated: ____ Exhaust Stack Diameter: 16 Inches

Engine Make/Model: Cat 3516 Miles/Hours: 17694 I.D.#: 251
Type of Equipment: 240 T Haul Truck

Fuel Specific Gravity: .830 @: 65 (°F)
Barometric Pressure: 30.09 Inches of Mercury
Intake Air Temperature: ______ (°F) Start Time: [illegible]

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	697	.95	.04	9	7.22	9.5	
	702	1.0	.04	10	7.27	9.4	
	706	.95	.04	11	7.30	9.4	
	715	.95	.05	12	7.26	9.4	
	719	.95	.05	12	7.29	9.4	
	715	.95	.04	12	7.54	9.0	
	724	.95	.05	10	7.28	9.5	
	727	.95	.06	10	7.54	9.1	
	738	.95	.05	12	7.26	9.4	
✓	745	.95	.05	12	7.35	9.3	

Spikes are created by something in the exhaust air flow

Operator used foot on throttle pattern then throttle lever

Smoke #8

End Time: ______

Names of Customer Personnel Participating in Test:

______ ______

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Test Date: [illegible]
Test Portion: Baseline: ✓ Treated: ______ Exhaust Stack Diameter: 10 Inches

Engine Make/Model: CAT 3612 Miles/Hours: 53071 I.D.#: 254
Type of Equipment: Haul Truck

Fuel Specific Gravity: .829 @: ______ (°F)
Barometric Pressure: 30.05 Inches of Mercury
Intake Air Temperature: ______ (°F) Start Time: ______

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	716	.5	.09	9	7.75	8.5	
	721	.55	.09	9	7.74	8.6	
	726	.55	.09	9	7.78	8.6	
	731	.5	.09	8	7.79	8.6	
	736	.55	.09	6	7.83	8.6	
	737	.55	.08	5	7.74	8.6	
	737	.6	.08	5	7.67	8.8	
	740	.55	.08	6	7.73	8.7	
	744	.55	.08	5	7.65	8.9	
	745	.55	.08	5	7.68	8.9	

Smoke #10

End Time ______

Names of Customer Personnel Participating in Test:

____________ ____________

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Test Date: 4/10/95

Test Portion: Baseline: ____ Treated: X Exhaust Stack Diameter: ___ Inches

Engine Make/Model: ____ Miles/Hours: 202022 I.D.#: 241

Type of Equipment: ____

Fuel Specific Gravity: .834 @: 58.4 (°F)

Barometric Pressure: ____ Inches of Mercury

Intake Air Temperature: ____ (°F) Start Time: 11:10

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	632	.85	.05	9	7.06	9.5	7.0
	638	.85	.05	8	7.03	9.6	
	645	.85	.05	9	7.00	9.6	
	647	.85	.05	9	7.00	9.7	
	652	.85	.05	10	6.95	9.7	
	658	.9	.05	10	6.92	9.7	
	661	.9	.05	11	6.99	9.6	
	664	.85	.05	10	6.9	9.7	
	666	.9	.05	10	6.9	9.7	
	669	.9	.05	10	6.9	9.7	

End Time ____

Names of Customer Personnel Participating in Test:

Barry

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Canyon Test Date: 4/10/95

Test Portion: Baseline: ______ Treated: ✓ Exhaust Stack Diameter: 10 Inches

Engine Make/Model: CAT 3516 Miles/Hours: 198926 I.D.#: 242

Type of Equipment: 793 Haul Truck

Fuel Specific Gravity: .839 @: 59.4 (°F)

Barometric Pressure: ______ Inches of Mercury

Intake Air Temperature: 62.4 (°F) Start Time: ______

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	690	1.0	.03	12	6.62	9.8	7.0
	697	1.0	.03	17	6.48	9.6	
	702	1.0	.03	17	6.42	9.7	
	703	1.0	.03	15	6.44	9.5	
	705	1.1	.03	14	6.50	9.6	
	710	1.1	.03	10	6.48	9.6	
	716	1.0	.02	10	6.45	9.7	
	720	1.0	.02	10	6.48	9.7	
	722	1.0	.02	10	6.44	9.8	
	707.2	1.05			6.479		

End Time ______

Names of Customer Personnel Participating in Test:

______ ______

Signature of Technicians:

______ ______

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Canyon Test Date: 4/14/95
Test Portion: Baseline: ________ Treated: ✓ Exhaust Stack Diameter: 16 Inches

Engine Make/Model: ________ Miles/Hours: ________ I.D.#: 246
Type of Equipment: ________

Fuel Specific Gravity: .837 @: 64.2 (°F)
Barometric Pressure: ________ Inches of Mercury
Intake Air Temperature: ________ (°F) Start Time: 11:00

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	726	.75	.05	6	6.74	10.4	7
	735	.75	.05	6	6.77	10.3	
	730	.75	.05	6	6.78	10.3	
	740	.75	.06	6	6.77	10.3	
	740	.75	.05	8	6.79	10.3	
	739	.75	.05	9	6.80	10.3	
	738	.75	.06	9	6.77	10.2	
	741	.75	.05	9	6.80	10.2	
	745	.75	.05	9	6.79	10.2	
	750		.06	9	6.79	10.2	

End Time ________

Names of Customer Personnel Participating in Test:

________ ________

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Canyon Test Date: 4/4/95
Test Portion: Baseline: ________ Treated: ✓ Exhaust Stack Diameter: 10 Inches

Engine Make/Model: Cat 3512 Miles/Hours: 125365 I.D.#: 251 #1 Sheet
Type of Equipment: 793 Haul Truck

Fuel Specific Gravity: .834 @: 66.8 (°F)
Barometric Pressure: ________ Inches of Mercury
Intake Air Temperature: 63.0 (°F) Start Time: 9:30

Reverse & Stall

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	753	.85	.07	6	7.30	10.2	8
	757	.85	.06	7	7.32	10.2	
	757	.85	.06	6	7.32	10.2	
	758	.85	.07	6	7.29	10.2	
	761	.8	.06	6	7.28	10.2	
	763	.8	.07	6	7.32	10.1	
	764	.85	.06	6	7.35	10.1	
	769	.85	.07	6	7.31	10.1	
	769	.85	.07	6	7.30	10.1	
	768	.85	.07	8	7.28	10.1	

CO_2 Dropped Down To 7.21, But Had To Get Truck Back Into Service

Continued on page 2

End Time ________

Names of Customer Personnel Participating in Test:

Annette

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company:________________ Location:________________ Test Date:__________
Test Portion: Baseline:________ Treated:________ Exhaust Stack Diameter: ___Inches

Engine Make/Model: ____________________ Miles/Hours:________ I.D.#: 251 #2 Shirk
Type of Equipment: ____

Fuel Specific Gravity: ________________ @:__________ (°F)
Barometric Pressure: ________________ Inches of Mercury
Intake Air Temperature: ______________ (°F) Start Time:__________

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	768	.85	.07	6	7.21	10.2	
	767	.80	.07	6	7.22	10.1	
	767	.85	.07	6	7.20	10.1	
	768	.85	.07	7	7.21	10.2	
	767.5	.839			7.219		

End Time__________

Names of Customer Personnel Participating in Test:

______________________ ______________________

Signature of Technicians:

Carbon Mass Balance Field Data Form

Company: Kennecott Location: Bingham Test Date: 4/11/95
Test Portion: Baseline: ______ Treated: X Exhaust Stack Diameter: ___ Inches

Engine Make/Model: ______________ Miles/Hours: 053892 I.D.#: 254
Type of Equipment: ______________

Fuel Specific Gravity: .831 @: 69 (°F)
Barometric Pressure: ______ Inches of Mercury
Intake Air Temperature: 63.0 (°F) Start Time: 1:05

RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	Smoke Number
1200	711	.55	.05	17	6.92	9.3	7
	713	.55	.05	17	6.92	9.2	
	716	.55	.05	17	6.90	9.3	
	717	.55	.05	19	6.92	9.3	
	718	.55	.05	19	6.92	9.2	
	719	.55	.05	19	6.92	9.3	
	722	.6	.05	18	6.92	9.3	
	723	.6	.05	18	6.92	9.3	
	725	.6	.05	19	6.94	9.3	
	727	.55	.05	23	6.99	9.2	

End Time ______

Names of Customer Personnel Participating in Test:

______________ ______________

Signature of Technicians: