Evaluation of the FFX Fuel Catalyst for Fuel Efficiency Improvement and Emissions Reductions Using the Carbon Mass Balance Test Procedure

Prepared for:
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INTRODUCTION

Environmental Consultants, LLC specializes in the modelling, monitoring and reporting of carbon-based emissions as well as naturally occurring radioactive materials.

As an independent consultant, is able to provide objective results for facilities wanting to determine their greenhouse gas emissions and fuel savings based on the institution of engineering or chemical controls in fleet and equipment operations.

Thank you for choosing us to represent you. Should you have any air/particulate evaluation or modelling needs in the future, please let us know.

CARBON MASS BALANCE TEST PROCEDURE

Fuel consumption measurements by reliable and accredited methods have been under constant review for many years. The weight of engineering evidence and scientific theory favors the Carbon Mass Balance method by which carbon measured in the engine exhaust gas is related to the carbon content of the fuel consumed. This method has certainly proven to be the most suitable for field-testing where minimizing equipment down time is a factor.

The inquiries of accuracy and reliability to which we refer include discussions from international commonwealth and government agencies responsible for the test procedure discussed herein. This procedure enumerates the data required for fuel consumption measurements by the “Carbon Mass Balance” or “exhaust gas analysis” method. The studies conducted show that the Carbon Mass Balance has been found to be a more precise fuel consumption test method than the alternative volumetric-gravimetric methods.

The Carbon Mass Balance test is a fundamental part of the Australian Standards AS2077-1982. Further, the Carbon Mass Balance test procedure has proven to be an intricate part of the United States EPA, FTP and HFET Fuel Economy Tests. Also, Ford Motor Company characterized the Carbon Mass Balance test procedure as being “at least as accurate as any other method of volumetric-gravimetric testing.” (SAE Paper No. 750002 Bruce Simpson, Ford Motor Company) Finally, the Carbon Mass Balance procedure is incorporated in the Federal Register Voluntary Fuel Economy Labeling Program, Volume 39.

The following photographic report documents a test performed in accordance with the Carbon Mass Balance test for the Thompson Creek Mining facility outside of Challis, Idaho. As will be documented, every effort is made to ensure that each test is consistent, repeatable, and precise.

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EXECUTIVE SUMMARY

The FFX fuel catalyst manufactured and marketed by MyDailyChoice, is a fuel borne catalyst wherein the primary active ingredient is a soluble organo-metallic chemistry that helps to reduce ignition delay by improving combustion chamber mixing through improved molecular dispersion.

The catalyst is a proprietary organo-metallic compound with the formula Fe(C5H5)2. It is the prototypical metallocene, a type of organo-metallic chemical compound, consisting of two cyclopentadienyl rings bound on opposite sides of a central soluble metal atom. Such organo-metallic compounds are also known as sandwich compounds. The rapid growth of organo-metallic chemistry is often attributed to the discovery of this soluble metal crystalline structure and its many analogues.

This proprietary organo-metallic derivative has many niche uses that exploit the unusual structure (ligand scaffolds, pharmaceutical candidates), robustness (anti-knock formulations, precursors to materials), and redox (reagents and redox standards). Such organo-metallic components and their derivatives are antiknock agents used in the fuel for gasoline and diesel engines.

Following discussions Equipment Availability and Reliability Specialist, Thompson Creek Metals Company, it was determined that a fuel consumption analysis should be conducted utilizing four (4) Caterpillar 789 C haul trucks equipped with 3516 Caterpillar engines. Similar engines, with dissimilar accumulated operating hours were evaluated in an attempt to determine the affects of the FFX fuel combustion catalyst on similar engines with varying engine hour accumulations and emissions profiles.

Figure 1. Thompson Creek Mining Facility

The Thompson Creek mine utilizes several haul trucks similar to those included in this test procedure. Further, there are also multiple pieces of varying equipment styles and types, which are used in the process of mining Molybdenum.

Figure 2. Example of Equipment Tested

A baseline test (untreated) was conducted on July 30, 2013 using the Carbon Mass Balance Test Procedure, after which the pre-selected test equipment was treated by adding the FFX fuel catalyst to a dedicated fuel supply tank that would later fuel the test vehicles on an as needed basis. On September 10, 2013, the test was then repeated (FFX treated) following the same parameters. The results are contained within this report.

These data showed that the average improvement in fuel consumption for all four pieces of equipment tested was 7.23% during steady state testing using the Carbon Mass Balance test procedure.

The treated engines also demonstrated a reduction in soot particulates in the range of 24% along with reductions in harmful exhaust related carbon fractions. Carbon dioxide reductions, based upon the measured reduction in fuel consumption, are also substantial.

TEST DETAILS

Baseline (untreated) fuel efficiency tests were conducted on all four (4) pieces of equipment on July 30, 2013, employing the Carbon Mass Balance (CMB) test procedure. MDC supplied sufficient product to correctly treat a dedicated fuel supply tank (tank no. 3) utilized for the purpose of routinely filling and treating the test equipment included in this evaluation. The test equipment was then operated with the FFX catalyst treated fuel for as close to 400 hours of engine operation as possible. At the end of the engine-conditioning period (September 10, 2013), the engine tests were repeated, reproducing all engine parameters. The final results, along with the data sheets, are contained within this report.

Figure 3. Tank Treatment of FFX Fuel Catalyst

TEST METHOD

Carbon Mass Balance (CMB) is a procedure whereby the mass of carbon in the exhaust is calculated as a measure of the fuel being burned. The elements measured in this test include the exhaust gas composition, its temperature, and the gas flow rate calculated from the differential pressure and exhaust stack cross sectional area. The CMB is central to both the US-EPA (FTP and HFET) and Australian engineering standard tests (AS2077-1982), although in field-testing we are unable to employ a chassis dynamometer. However, in the case of a stationary equipment test, the engine can be loaded sufficiently to demonstrate fuel consumption trends and potential.

The CMB formula and equations employed in calculating the carbon flow are supplied, in part, by doctors' of Combustion Engineering at the university and scientific research facility level (see Appendix V; Carbon Mass Balance Equation).

The CMB test procedure follows a prescribed regimen, wherein every pertinent detail of engine operation is monitored to ensure the accuracy of the test procedure. Cursory to performing the test, it is imperative to understand the quality of fuel utilized in the evaluation. As important, the quality of fuel must be consistent throughout the entirety of the process.

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Figure 4. Fuel Analysis

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Fuel density and temperature tests are performed for both the baseline and treated segments of the evaluation to determine the energy content of the fuel. A .800 to .910 Precision Hydrometer, columnar flask and Raytek Minitemp are utilized to determine the fuel density for each prescribed segment of the evaluation.

Next, and essential to the Carbon Mass Balance procedure, is test equipment that is mechanically sound and free from defect. Careful consideration and equipment screening is utilized to verify the mechanical stability of each piece of test equipment. Preliminary data is scrutinized to disqualify all equipment that may be mechanically suspect. Once the equipment selected process is complete, the Carbon Mass Balance test takes only 25 to 20 minutes, per unit, to perform.

Once the decision is made to test a certain piece of equipment, pertinent engine criteria needs to be evaluated as the Carbon Mass Balance procedure continues.

When the selection process is complete, engine RPM is increased and locked in position. This allows the engine fluids, block temperature and exhaust stream gasses to stabilize. Data cannot be collected when there is irregular fluctuation in engine RPM and exhaust constituent levels. Therefore, all engine operating conditions must be stable and consistent.

Figure 5. Maintaining Constant Load Conditions

An aftermarket throttle position lock is utilized, as one method, to secure engine RPM. This provides a steady state condition in which consistent data can be collected.

Should the engine RPM fluctuate erratically and uncontrollably, the test unit would be disqualified from further consideration.

Next, engine RPM and fluid temperatures are monitored throughout the Carbon Mass Balance evaluation. As important, exhaust manifold temperatures are monitored to ensure that engine combustion is consistent in all cylinders. It is imperative that the engine achieve normal operating conditions before any testing begins.

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Figure 6. Monitoring Engine Parameters

Once engine fluid levels have reached normal operating conditions the Carbon Mass Balance study may begin. The above photograph shows that the engine RPM is locked in place at 1300 RPM. It should be noted that any deviation in RPM, temperature, either fluid or exhaust, would cause this unit to be eliminated from the evaluation due to mechanical inconsistencies.

Once all of the mechanical criteria are met, data acquisition can commence; it is necessary to monitor the temperature and pressure of the exhaust stream. Carbon Mass Balance data cannot be collected until the engine exhaust temperature has peaked. Exhaust temperature is monitored carefully for this reason.

Figure 7. Exhaust-side, Temperature Monitoring

Once the exhaust temperature has stabilized, the test unit has reached its peak operating temperature. Exhaust temperature is critical to the completion of a successful evaluation, since temperature changes identify changes in load and RPM. As previously discussed, RPM and load must remain constant during the Carbon Mass Balance study.

When all temperatures are stabilized, and the desired operating parameters are achieved; it is time to insert the emissions sampling probe into the exhaust tip of each piece of equipment utilized in the study group. The probe has a non-dispersive head, which allows for random exhaust sampling throughout the cross section of the exhaust.

Figure 8. Exhaust-side, Emissions Monitoring

While the emission-sampling probe is in place, and data is being collected, exhaust temperature and pressure are monitored throughout the entirety of the Carbon Mass Balance procedure. This photograph shows the typical location of the exhaust emissions sampling probe.

While data is being collected, exhaust pressure is monitored, once again, as a tool to control load and RPM fluctuations. Exhaust pressure is proportional to load. Therefore, as one increases, or decreases, so in turn does the other. The Carbon Mass Balance test is unique in that all parameters that have a dramatic affect on fuel consumption, in a volumetric test, are controlled and monitored throughout the entire evaluation. This ensures the accuracy of the data being collected. Exhaust pressure is nothing more than an accumulation of combustion events that are distributed through the exhaust matrix.

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Figure 9. Magnahelic Gauge

The photograph above and below identifies one method in which exhaust pressure and air inlet velocity can be monitored during the Carbon Mass Balance test procedure. In this case, exhaust pressure and air inlet velocity are ascertained through the use of a Magnahelic gauge. This type of stringent regime further documents the inherent accuracy of the Carbon Mass Balance test.

Figure 10. Exhaust-side, Pressure Monitoring

At the conclusion of the Carbon Mass Balance test, a soot particulate test is performed to determine the engine exhaust particulate level. This valuable procedure helps to determine the soot particulate content in the exhaust stream. Soot particulates are the most obvious and compelling sign of high emissions levels. Any attempt to reduce soot particulates places all industry in a favorable position with environmental policy as well as the general public.

Figure 11. Exhaust-side, Soot Monitoring

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The above photograph demonstrates a typical method in which soot particulate volume is monitored during the Carbon Mass Balance test. This method is the Bacharach Smoke Spot test. It is extremely accurate, portable, and repeatable. It is a valuable tool in smoke spot testing when comparing baseline (untreated) exhaust to catalyst treated exhaust.

Finally, the data being recorded is collected through a non-dispersive, infrared analyzer. Equipment such as this is EPA approved and CFR 40 rated. This analyzer has a high degree of accuracy and repeatability. It is central to the Carbon Mass Balance procedure in that it identifies baseline carbon and oxygen levels, relative to their change with catalyst treated fuel in the exhaust stream. The data accumulated is very accurate as long as the criteria leading up to the accumulation of data is controlled. For this reason, the Carbon Mass Balance test is superior to any other test method utilized. It eliminates a multitude of variables that can adversely affect the outcome and reliability of any fuel consumption evaluation.

Figure 12. Horiba Gas Analyzer

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The above photograph identifies one type of analyzer used to perform the Carbon Mass Balance test. The analyzer is calibrated with known reference gases before the baseline and treated test segments begin.

Figure 13. Gas Analyzer Calibration

The data collected from this analyzer during the baseline segment of the evaluation is then computed and compared to the accumulated catalyst treated carbon data and the carbon contained within the raw diesel fuel. A fuel consumption performance factor is then calculated from the data. The baseline performance factor is compared with the catalyst treated performance factor. The difference between the two performance factors identifies the change in fuel consumption during the Carbon Mass Balance test procedure.

Figure 14. Treated Fuel Tank

Finally, essential to performing the aforementioned test procedure is the method in which the task for dosing fuel is performed. It is critical to the success of the Carbon Mass Balance procedure to ensure that the equipment evaluated be given meticulous care and consideration to advance the process of testing. For the purpose of this evaluation, a 20,000 gallon bulk fuel supply tank was utilized to ensure the equipment being evaluated was regularly treated with the required concentration of the FFX fuel catalyst.

INSTRUMENTATION

Precision state of the art instrumentation was 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 purpose are listed below:

- Measurement of exhaust gas constituents HC, CO, CO2 and O2, by Horiba Mexa Series, four gas infrared analyser.

  Note: The Horiba MEXA emissions analyser is calibrated with the same reference gas for both the baseline and treated segments of the evaluation. It

is also serviced and calibrated prior to each series of CMB engine efficiency tests.

- Temperature measurement; by Fluke Model 52K/J digital thermometer.
- Exhaust differential pressure by Dwyer Magnahelic.
- Ambient pressure determination by use of Brunton ADC altimeter/barometer.

The exhaust soot particulates are also measured during this test program. Exhaust gas sample evaluation of particulate by use of a Bacharach True Spot smoke meter.

TEST RESULTS

As part of this discussion, fuel efficiency, soot particulate tests and driver observations will be discussed.

Fuel Efficiency

A summary of the CMB fuel efficiency results achieved, in this test program, is provided in the following tables and appendices. See Table 1, and Individual Carbon Mass Balance results, in Appendix II.

Table 1 provides the average test results for all pieces of equipment before and after the FFX fuel catalyst treatment (see graph II, Appendix I). Total hours accumulated since the baseline period of the Carbon Mass Balance test procedure are contained in the CMB data sheets (see Appendix II; Carbon Mass Balance Compilation Sheets).

TABLE 1. Test Results

Test Segment	Acc. Hours	Fuel Change
T-78 Treated	531	-7.0%
T-80 Treated	514	-7.1%
T-86 Treated	531	-7.5%
T-89 Treated	547	-7.3%
Average (Absolute)		**-7.23%**

The computer printouts of the calculated CMB test results are located in Appendix II. The raw engine data sheets used to calculate the CMB are contained in Appendix III. The raw data sheets and Carbon Mass Balance sheets show and account for the environmental and ambient conditions during the evaluation.

Soot Particulate Tests

Concurrent with CMB data extraction, soot particulate measurements were conducted. The results of these tests are summarized in Table 2. Reductions in soot particulates are the most apparent and immediate. Laboratory testing indicates that carbon and solid particulate reductions occur before observed fuel reductions. Studies show and the manufacturer suggests that a minimum 300 to 400 hours of FFX fuel catalyst treated engine operation are necessary before the conditioning period is complete. Then, and only then, will fuel consumption improvements be maximized.

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TABLE 2. Soot Particulate Measurements

Fuel Type .830 @ 60 degrees F. Diesel	**Soot Particulates**
T-78	
Untreated	6.64 mg/m^3
Treated	4.85 mg/m^3
	- 27%
T-80	
Untreated	6.14 mg/m^3
Treated	4.61 mg/m^3
	- 25%
T-86	
Untreated	5.86 mg/m^3
Treated	4.51 mg/m^3
	- 23%
T-89	
Untreated	5.57 mg/m^3
Treated	4.42 mg/m^3
	- 21%
Absolute Average	**- 24%**

The reduction in soot particulate density (the mass of the smoke particles per volume of air) was reduced by a minimum average of 24% (See Graph 1, Appendix I). Concentration levels were provided by using a Bacharach Smoke Spot tester.

Driver Observations

Drivers noted a marked increase in power and speed. One driver stated he was able to climb out of the pit in a higher gear than before, another claimed he was able to climb out of the pit at around 9 mph, much faster than normal, hauling more than 200 tons. Others reported that the trucks were faster and that none of the other trucks were able to catch up to them. In addition, less visible exhaust smoke was observed with increased RPM and power draw on the engine. It should be noted, that fuel consumption and/or horsepower will not be experienced simultaneously. In general, one combustion generated component will necessarily be sacrificed at the expense of the other.

CONCLUSION

These carefully controlled engineering standard test procedures conducted on all four Caterpillar haul trucks provide evidence of reduced fuel consumption in the range of 7.23%. In general, improvements utilizing the CMB test, under static test conditions, generate results 2% - 3% less than those results generated with an applied load.

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The FFX fuel catalyst’s effect on improved combustion is also evidenced by an observed reduction in soot particulates (smoke) in the range of 24% (see Soot Particulate Graph: Appendix I). Similar reductions in other harmful carbon emissions likewise substantiate an improvement in combustion created by the use of FFX fuel combustion catalyst (see Raw Data Sheets: Appendix III and Emissions Reductions: Appendix VI).

In addition to the fuel consumption analysis, a detailed compilation of carbon Greenhouse emissions reductions were determined. The study documented a significant reduction in annual $C0_2$ (Greenhouse gasses) emissions of 1,847 metric tonnes. Reductions in Nitrogen and Methane levels were also observed (see Appendix IV).

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Appendix I

Exhaust Particulate and Fuel Graphs

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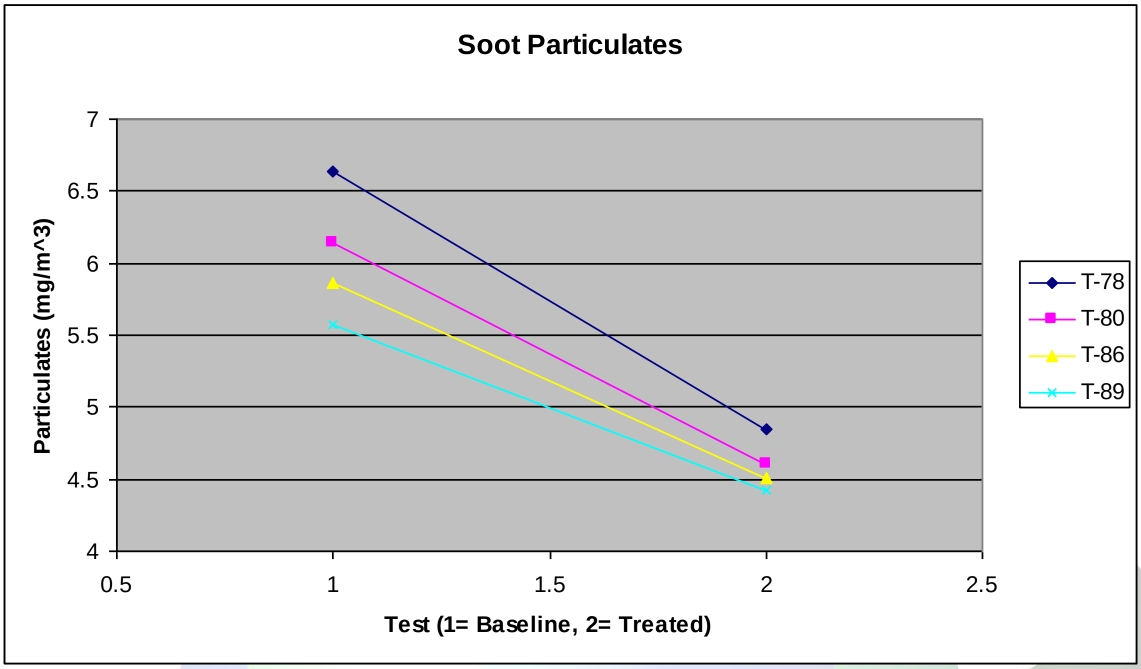
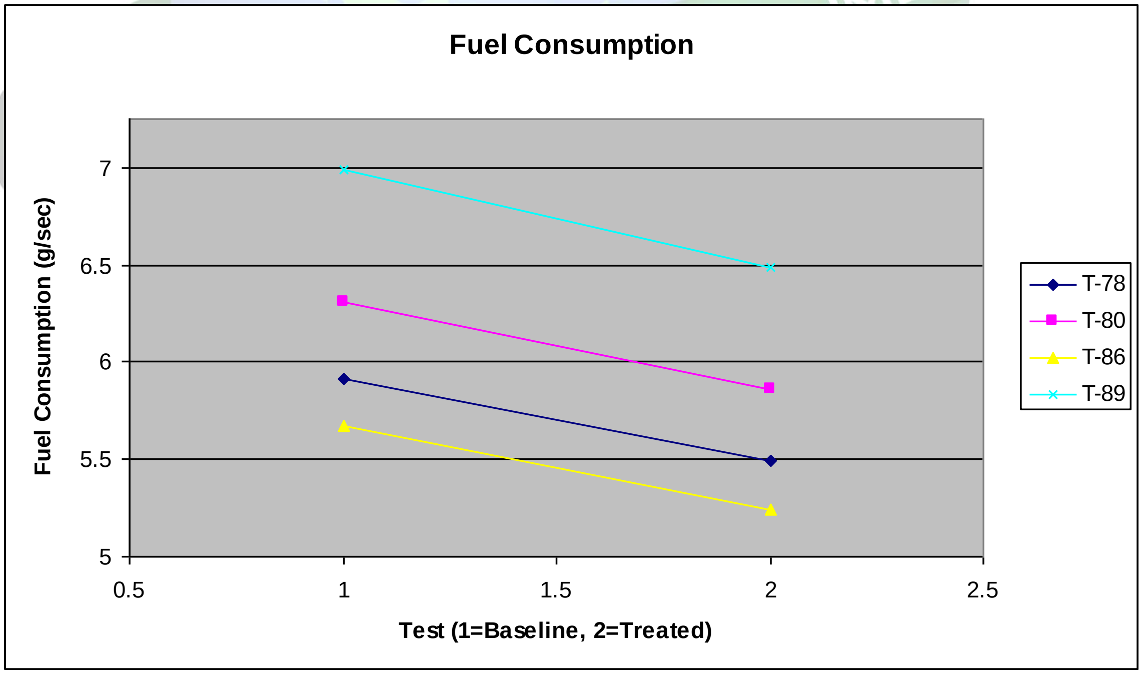


Soot Particulate Graph



Fuel Consumption Graph

Appendix II

Carbon Mass Balance Compilation Sheets

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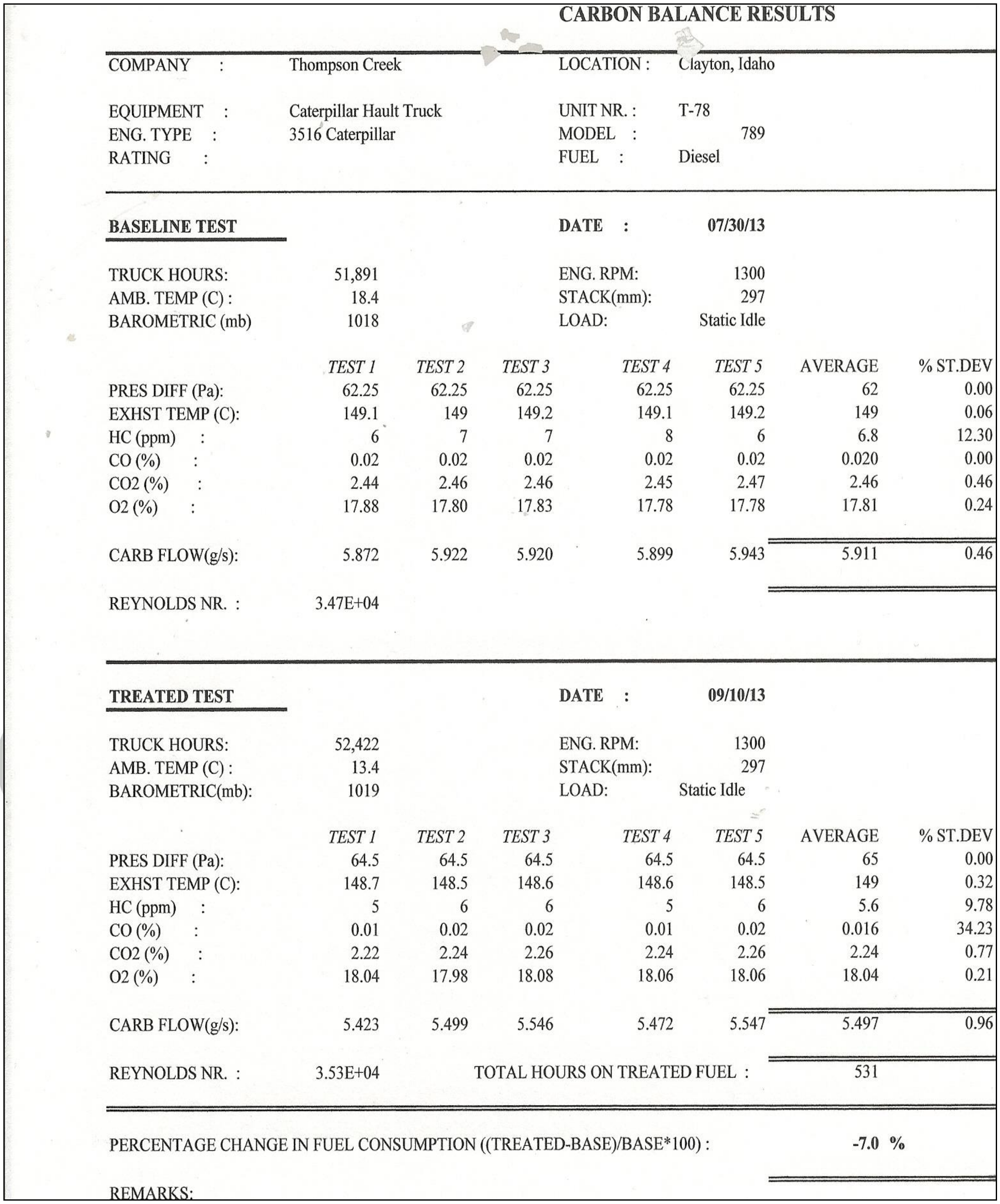


CARBON BALANCE RESULTS

COMPANY : Thompson Creek
LOCATION : Clayton, Idaho

EQUIPMENT : Caterpillar Hault Truck
ENG. TYPE : 3516 Caterpillar
RATING :
UNIT NR. : T-78
MODEL : 789
FUEL : Diesel

BASELINE TEST

DATE : 07/30/13

TRUCK HOURS: 51,891
AMB. TEMP (C) : 18.4
BAROMETRIC (mb) 1018
ENG. RPM: 1300
STACK(mm): 297
LOAD: Static Idle

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	62.25	62.25	62.25	62.25	62.25	62	0.00
EXHST TEMP (C):	149.1	149	149.2	149.1	149.2	149	0.06
HC (ppm) :	6	7	7	8	6	6.8	12.30
CO (%) :	0.02	0.02	0.02	0.02	0.02	0.020	0.00
CO2 (%) :	2.44	2.46	2.46	2.45	2.47	2.46	0.46
02 (%) :	17.88	17.80	17.83	17.78	17.78	17.81	0.24
CARB FLOW(g/s):	5.872	5.922	5.920	5.899	5.943	5.911	0.46

REYNOLDS NR. : 3.47E+04

TREATED TEST

DATE : 09/10/13

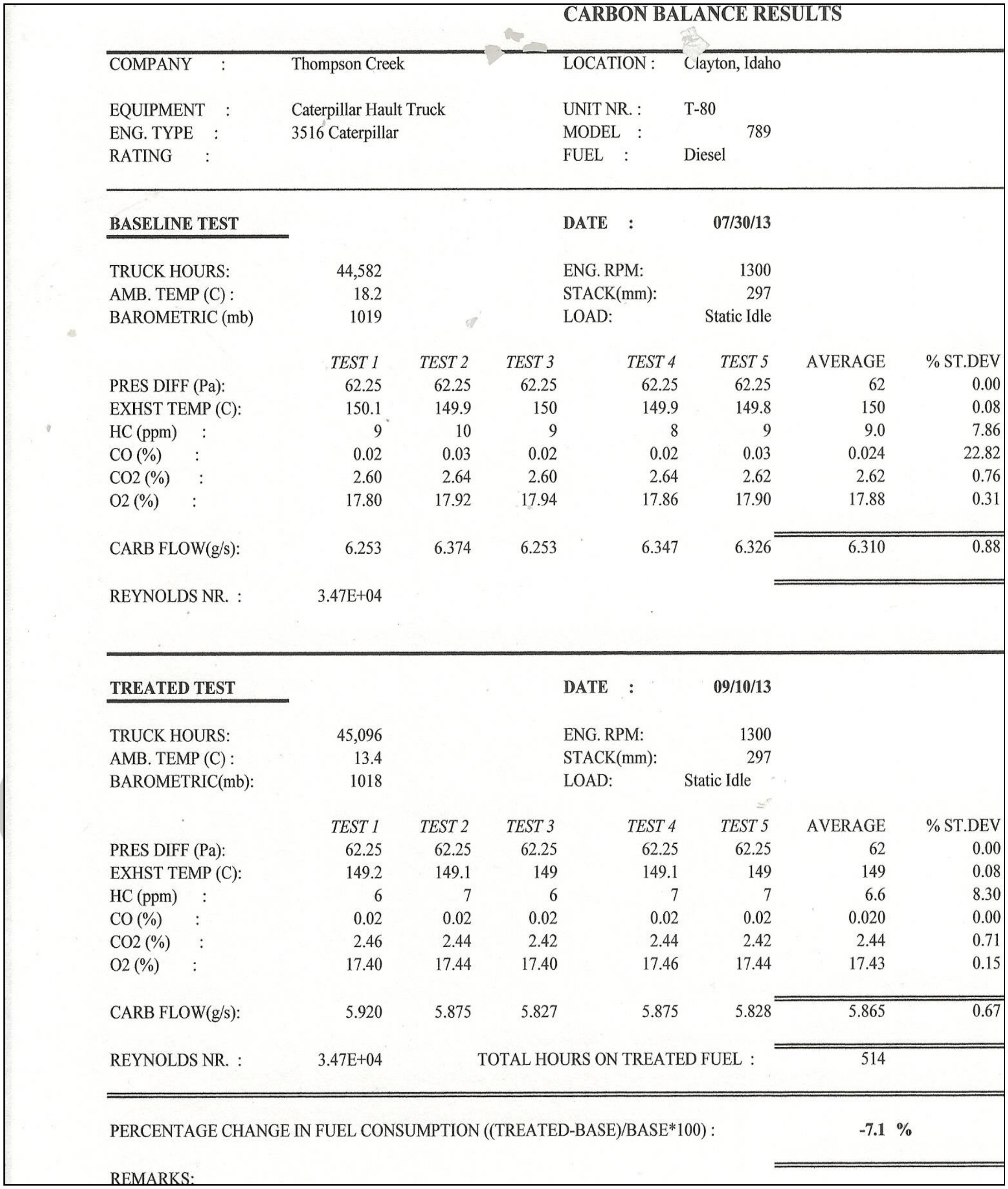
TRUCK HOURS: 52,422
AMB. TEMP (C) : 13.4
BAROMETRIC(mb): 1019
ENG. RPM: 1300
STACK(mm): 297
LOAD: Static Idle

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	64.5	64.5	64.5	64.5	64.5	65	0.00
EXHST TEMP (C):	148.7	148.5	148.6	148.6	148.5	149	0.32
HC (ppm) :	5	6	6	5	6	5.6	9.78
CO (%) :	0.01	0.02	0.02	0.01	0.02	0.016	34.23
CO2 (%) :	2.22	2.24	2.26	2.24	2.26	2.24	0.77
02 (%) :	18.04	17.98	18.08	18.06	18.06	18.04	0.21
CARB FLOW(g/s):	5.423	5.499	5.546	5.472	5.547	5.497	0.96

REYNOLDS NR. : 3.53E+04
TOTAL HOURS ON TREATED FUEL : 531

PERCENTAGE CHANGE IN FUEL CONSUMPTION ((TREATED-BASE)/BASE*100) : **-7.0 %**

REMARKS:



CARBON BALANCE RESULTS

COMPANY : Thompson Creek
LOCATION : Clayton, Idaho

EQUIPMENT : Caterpillar Hault Truck
ENG. TYPE : 3516 Caterpillar
RATING :
UNIT NR. : T-80
MODEL : 789
FUEL : Diesel

BASELINE TEST

DATE : 07/30/13

TRUCK HOURS: 44,582
AMB. TEMP (C) : 18.2
BAROMETRIC (mb) 1019
ENG. RPM: 1300
STACK(mm): 297
LOAD: Static Idle

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	62.25	62.25	62.25	62.25	62.25	62	0.00
EXHST TEMP (C):	150.1	149.9	150	149.9	149.8	150	0.08
HC (ppm) :	9	10	9	8	9	9.0	7.86
CO (%) :	0.02	0.03	0.02	0.02	0.03	0.024	22.82
CO2 (%) :	2.60	2.64	2.60	2.64	2.62	2.62	0.76
O2 (%) :	17.80	17.92	17.94	17.86	17.90	17.88	0.31
CARB FLOW(g/s):	6.253	6.374	6.253	6.347	6.326	6.310	0.88
REYNOLDS NR. :	3.47E+04						

TREATED TEST

DATE : 09/10/13

TRUCK HOURS: 45,096
AMB. TEMP (C) : 13.4
BAROMETRIC(mb): 1018
ENG. RPM: 1300
STACK(mm): 297
LOAD: Static Idle

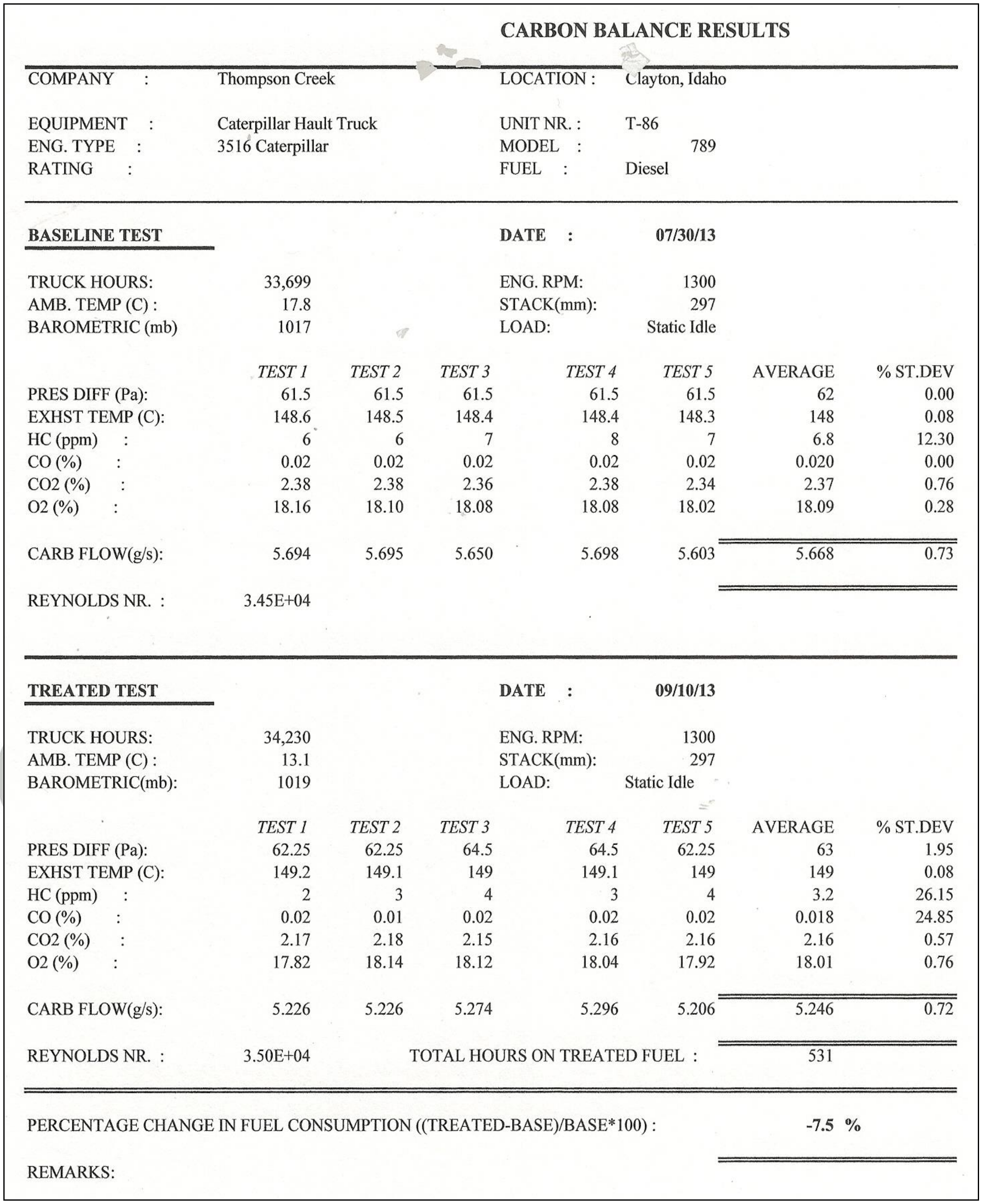
	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	62.25	62.25	62.25	62.25	62.25	62	0.00
EXHST TEMP (C):	149.2	149.1	149	149.1	149	149	0.08
HC (ppm) :	6	7	6	7	7	6.6	8.30
CO (%) :	0.02	0.02	0.02	0.02	0.02	0.020	0.00
CO2 (%) :	2.46	2.44	2.42	2.44	2.42	2.44	0.71
O2 (%) :	17.40	17.44	17.40	17.46	17.44	17.43	0.15
CARB FLOW(g/s):	5.920	5.875	5.827	5.875	5.828	5.865	0.67

REYNOLDS NR. : 3.47E+04

TOTAL HOURS ON TREATED FUEL : 514

PERCENTAGE CHANGE IN FUEL CONSUMPTION ((TREATED-BASE)/BASE*100) : **-7.1 %**

REMARKS:



CARBON BALANCE RESULTS

COMPANY : Thompson Creek
LOCATION : Clayton, Idaho

EQUIPMENT : Caterpillar Hault Truck
UNIT NR. : T-86
ENG. TYPE : 3516 Caterpillar
MODEL : 789
RATING :
FUEL : Diesel

BASELINE TEST

DATE : 07/30/13

TRUCK HOURS: 33,699
AMB. TEMP (C) : 17.8
BAROMETRIC (mb) 1017
ENG. RPM: 1300
STACK(mm): 297
LOAD: Static Idle

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	61.5	61.5	61.5	61.5	61.5	62	0.00
EXHST TEMP (C):	148.6	148.5	148.4	148.4	148.3	148	0.08
HC (ppm) :	6	6	7	8	7	6.8	12.30
CO (%) :	0.02	0.02	0.02	0.02	0.02	0.020	0.00
CO2 (%) :	2.38	2.38	2.36	2.38	2.34	2.37	0.76
O2 (%) :	18.16	18.10	18.08	18.08	18.02	18.09	0.28
CARB FLOW(g/s):	5.694	5.695	5.650	5.698	5.603	5.668	0.73

REYNOLDS NR. : 3.45E+04

TREATED TEST

DATE : 09/10/13

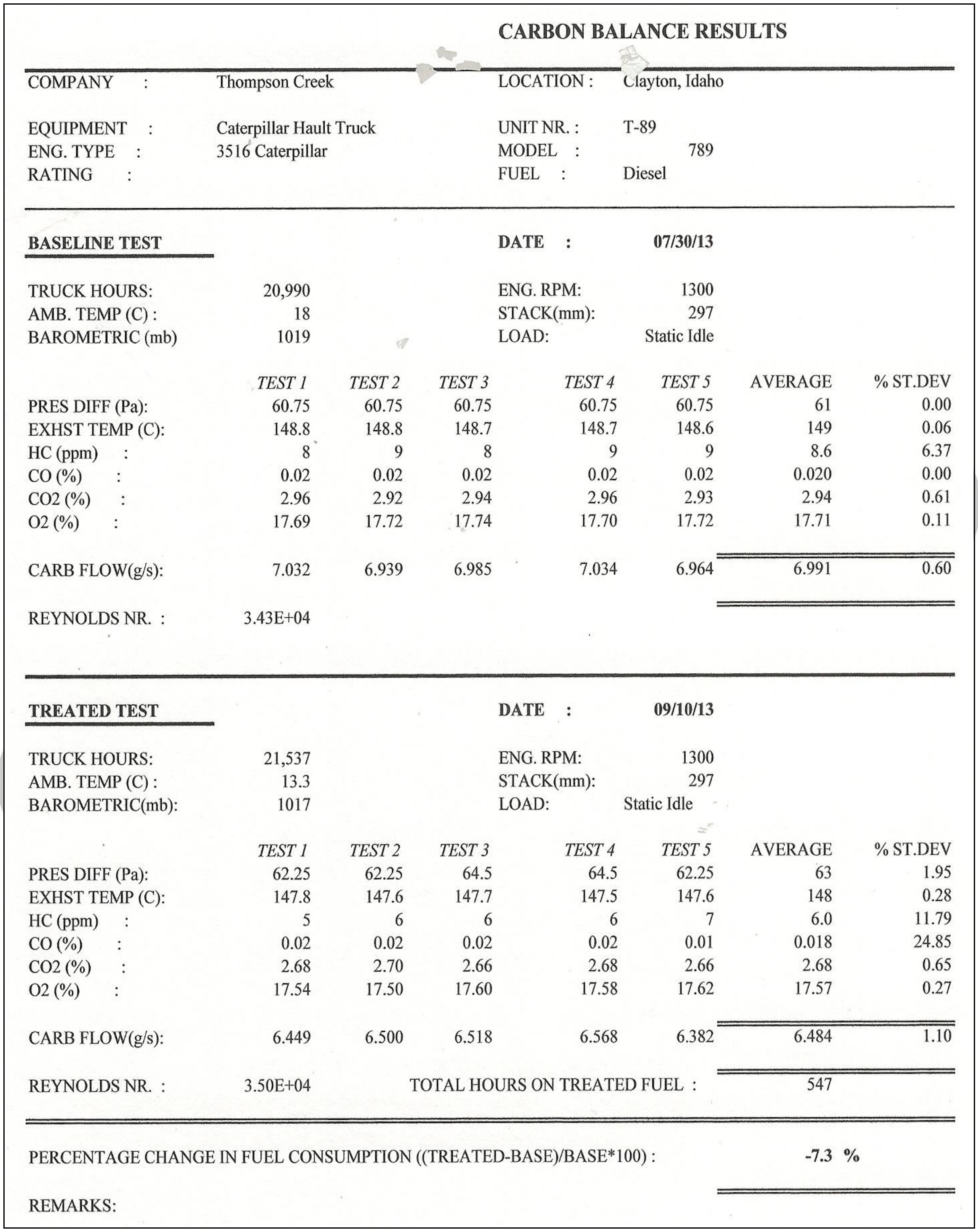
TRUCK HOURS: 34,230
AMB. TEMP (C) : 13.1
BAROMETRIC(mb): 1019
ENG. RPM: 1300
STACK(mm): 297
LOAD: Static Idle

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	62.25	62.25	64.5	64.5	62.25	63	1.95
EXHST TEMP (C):	149.2	149.1	149	149.1	149	149	0.08
HC (ppm) :	2	3	4	3	4	3.2	26.15
CO (%) :	0.02	0.01	0.02	0.02	0.02	0.018	24.85
CO2 (%) :	2.17	2.18	2.15	2.16	2.16	2.16	0.57
O2 (%) :	17.82	18.14	18.12	18.04	17.92	18.01	0.76
CARB FLOW(g/s):	5.226	5.226	5.274	5.296	5.206	5.246	0.72

REYNOLDS NR. : 3.50E+04
TOTAL HOURS ON TREATED FUEL : 531

PERCENTAGE CHANGE IN FUEL CONSUMPTION ((TREATED-BASE)/BASE*100) : **-7.5 %**

REMARKS:



CARBON BALANCE RESULTS

COMPANY : Thompson Creek
LOCATION : Clayton, Idaho

EQUIPMENT : Caterpillar Hault Truck
ENG. TYPE : 3516 Caterpillar
RATING :
UNIT NR. : T-89
MODEL : 789
FUEL : Diesel

BASELINE TEST

DATE : 07/30/13

TRUCK HOURS: 20,990
AMB. TEMP (C) : 18
BAROMETRIC (mb) 1019
ENG. RPM: 1300
STACK(mm): 297
LOAD: Static Idle

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	60.75	60.75	60.75	60.75	60.75	61	0.00
EXHST TEMP (C):	148.8	148.8	148.7	148.7	148.6	149	0.06
HC (ppm) :	8	9	8	9	9	8.6	6.37
CO (%) :	0.02	0.02	0.02	0.02	0.02	0.020	0.00
CO2 (%) :	2.96	2.92	2.94	2.96	2.93	2.94	0.61
O2 (%) :	17.69	17.72	17.74	17.70	17.72	17.71	0.11
CARB FLOW(g/s):	7.032	6.939	6.985	7.034	6.964	6.991	0.60

REYNOLDS NR. : 3.43E+04

TREATED TEST

DATE : 09/10/13

TRUCK HOURS: 21,537
AMB. TEMP (C) : 13.3
BAROMETRIC(mb): 1017
ENG. RPM: 1300
STACK(mm): 297
LOAD: Static Idle

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	62.25	62.25	64.5	64.5	62.25	63	1.95
EXHST TEMP (C):	147.8	147.6	147.7	147.5	147.6	148	0.28
HC (ppm) :	5	6	6	6	7	6.0	11.79
CO (%) :	0.02	0.02	0.02	0.02	0.01	0.018	24.85
CO2 (%) :	2.68	2.70	2.66	2.68	2.66	2.68	0.65
O2 (%) :	17.54	17.50	17.60	17.58	17.62	17.57	0.27
CARB FLOW(g/s):	6.449	6.500	6.518	6.568	6.382	6.484	1.10

REYNOLDS NR. : 3.50E+04

TOTAL HOURS ON TREATED FUEL : 547

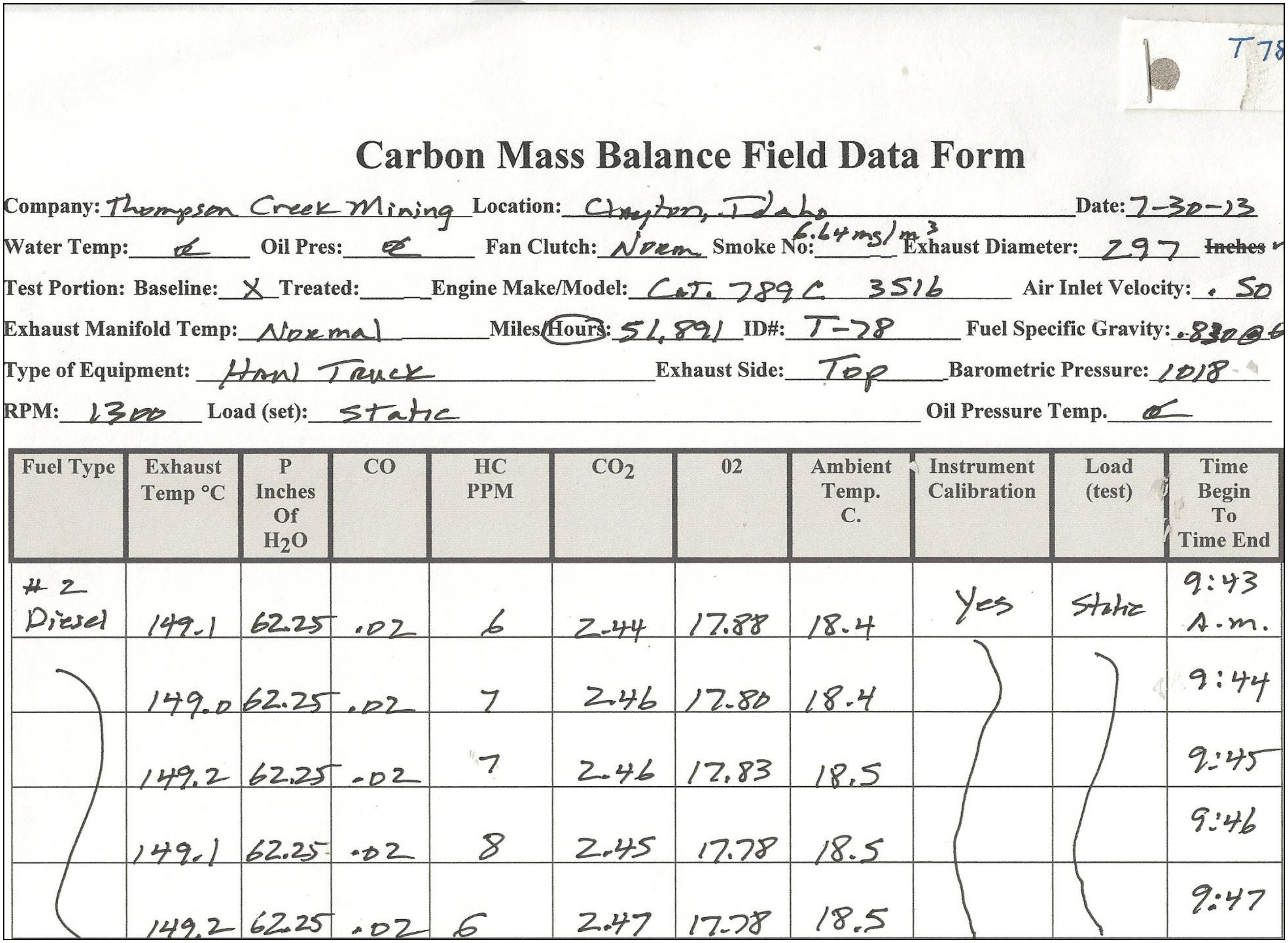
PERCENTAGE CHANGE IN FUEL CONSUMPTION ((TREATED-BASE)/BASE*100) : **-7.3 %**

REMARKS:

Appendix III

Raw Data Sheets

EMISSIONS & ENVIRONMENTAL



T 78

Carbon Mass Balance Field Data Form

Company: Thompson Creek Mining Location: Clayton, Idaho Date: 7-30-13

Water Temp: 0 Oil Pres: 0 Fan Clutch: Norm Smoke No: 6.64 ms/m³ Exhaust Diameter: 297 ~~Inches~~

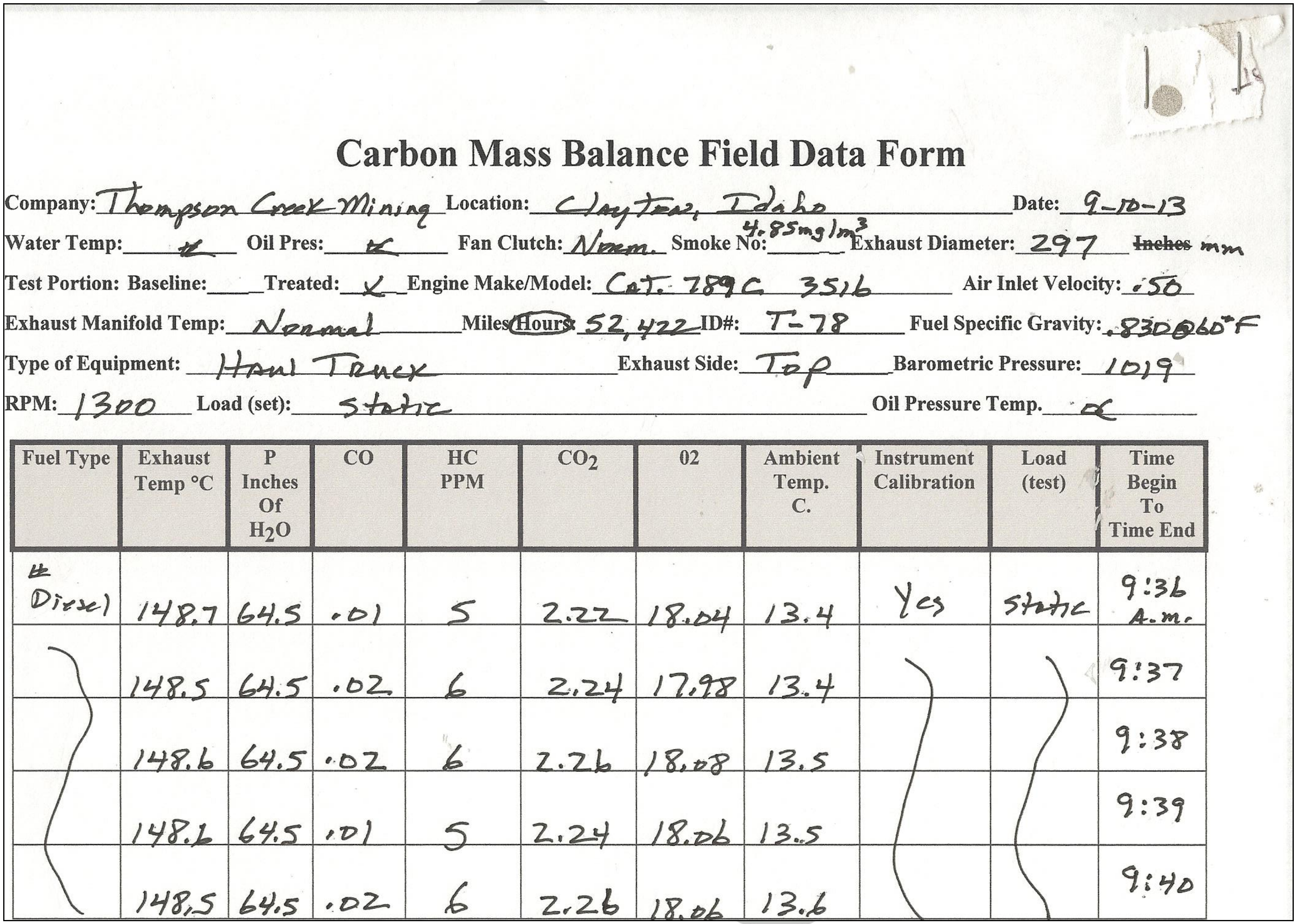
Test Portion: Baseline: X Treated: ___ Engine Make/Model: Cat. 789C 3516 Air Inlet Velocity: .50

Exhaust Manifold Temp: Normal Miles/[✓ Hours]: 51,891 ID#: T-78 Fuel Specific Gravity: .830@

Type of Equipment: Haul Truck Exhaust Side: Top Barometric Pressure: 1018

RPM: 1300 Load (set): Static Oil Pressure Temp. 0

Fuel Type	Exhaust Temp °C	P Inches Of H_2O	CO	HC PPM	CO_2	02	Ambient Temp. C.	Instrument Calibration	Load (test)	Time Begin To Time End
#2 Diesel	149.1	62.25	.02	6	2.44	17.88	18.4	Yes	Static	9:43 A.m.
	149.0	62.25	.02	7	2.46	17.80	18.4			9:44
	149.2	62.25	.02	7	2.46	17.83	18.5			9:45
	149.1	62.25	.02	8	2.45	17.78	18.5			9:46
	149.2	62.25	.02	6	2.47	17.78	18.5			9:47



Carbon Mass Balance Field Data Form

Company: Thompson Creek Mining Location: Clayton, Idaho Date: 9-10-13

Water Temp: ø Oil Pres: ø Fan Clutch: Norm. Smoke No: 4.85mg/m3 Exhaust Diameter: 297 ~~Inches~~ mm

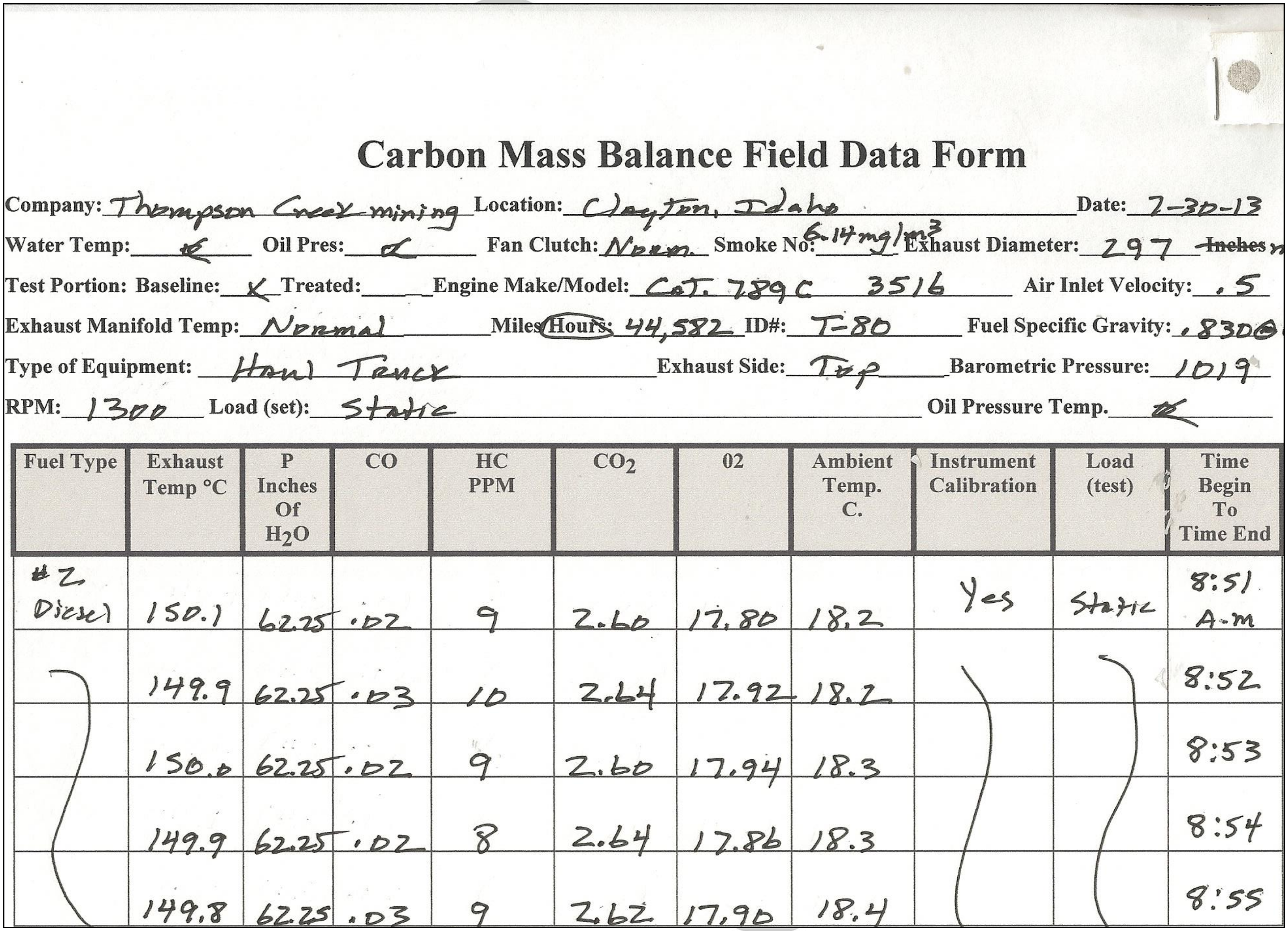
Test Portion: Baseline: ___ Treated: ✓ Engine Make/Model: Cat. 789C 3516 Air Inlet Velocity: .50

Exhaust Manifold Temp: Normal Miles/[✓ Hours]: 52,422 ID#: T-78 Fuel Specific Gravity: .830@60°F

Type of Equipment: Haul Truck Exhaust Side: Top Barometric Pressure: 1019

RPM: 1300 Load (set): static Oil Pressure Temp. ø

Fuel Type	Exhaust Temp °C	P Inches Of H_2O	CO	HC PPM	CO_2	02	Ambient Temp. C.	Instrument Calibration	Load (test)	Time Begin To Time End
#2 Diesel	148.7	64.5	.01	5	2.22	18.04	13.4	Yes	static	9:36 A.m.
	148.5	64.5	.02	6	2.24	17.98	13.4			9:37
	148.6	64.5	.02	6	2.26	18.08	13.5			9:38
	148.6	64.5	.01	5	2.24	18.06	13.5			9:39
	148.5	64.5	.02	6	2.26	18.06	13.6			9:40



Carbon Mass Balance Field Data Form

Company: Thompson Creek mining Location: Clayton, Idaho Date: 7-30-13

Water Temp: 0 Oil Pres: 0 Fan Clutch: Norm. Smoke No: 6.14mg/m3 Exhaust Diameter: 297 ~~Inches~~ m

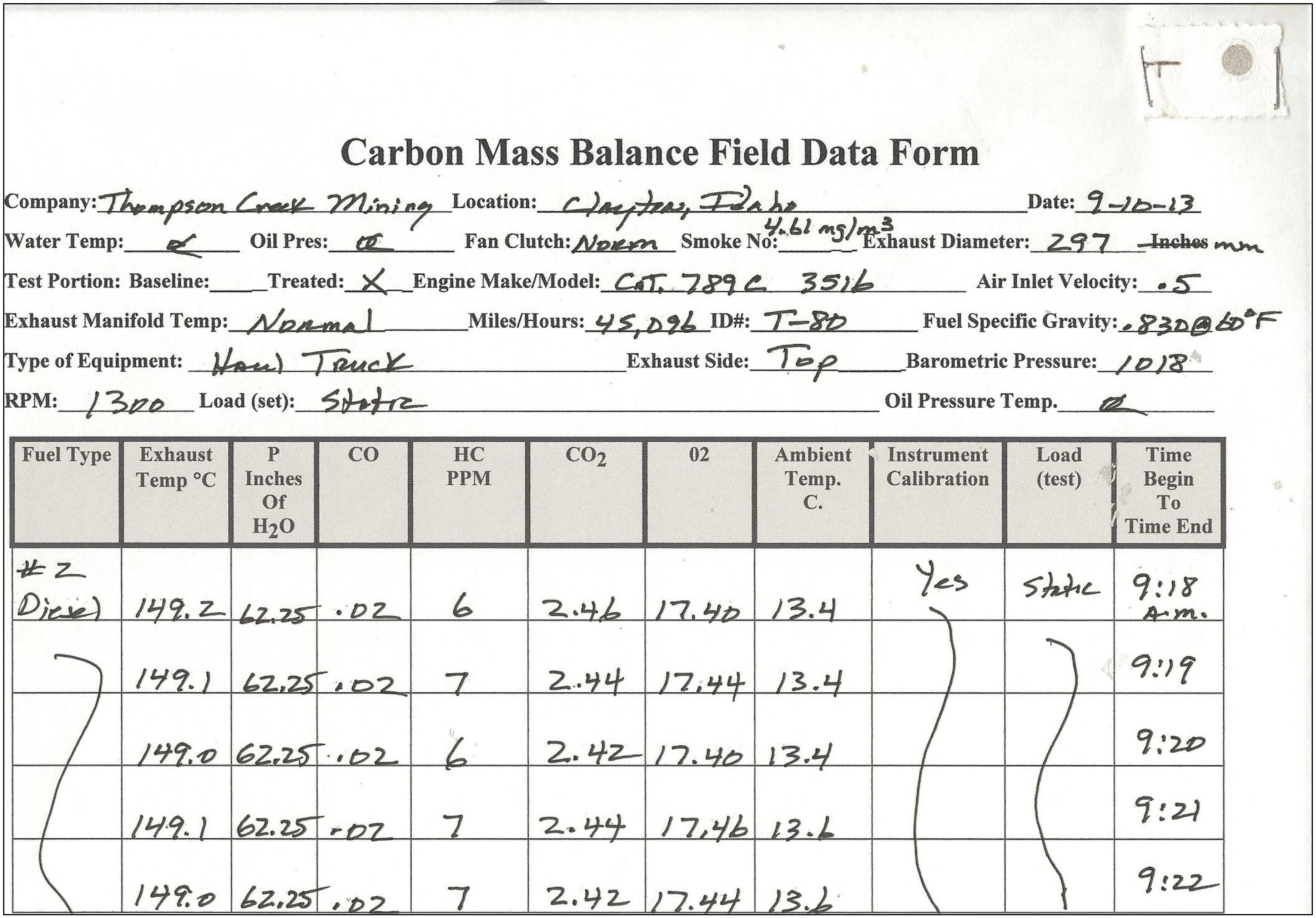
Test Portion: Baseline: X Treated: ___ Engine Make/Model: CAT. 789C 3516 Air Inlet Velocity: .5

Exhaust Manifold Temp: Normal Miles/[✓ Hours]: 44,582 ID#: T-80 Fuel Specific Gravity: .830

Type of Equipment: Haul Truck Exhaust Side: Top Barometric Pressure: 1019

RPM: 1300 Load (set): Static Oil Pressure Temp. 0

Fuel Type	Exhaust Temp °C	P Inches Of H_2O	CO	HC PPM	CO_2	02	Ambient Temp. C.	Instrument Calibration	Load (test)	Time Begin To Time End
#2 Diesel	150.1	62.25	.02	9	2.60	17.80	18.2	Yes	Static	8:51 A.M
	149.9	62.25	.03	10	2.64	17.92	18.2			8:52
	150.0	62.25	.02	9	2.60	17.94	18.3			8:53
	149.9	62.25	.02	8	2.64	17.86	18.3			8:54
	149.8	62.25	.03	9	2.62	17.90	18.4			8:55



T

Carbon Mass Balance Field Data Form

Company: Thompson Creek Mining **Location:** Clayton, Idaho **Date:** 9-10-13

Water Temp: 0 **Oil Pres:** 0 **Fan Clutch:** Norm **Smoke No:** 4.61 mg/m3 **Exhaust Diameter:** 297 ~~Inches~~ mm

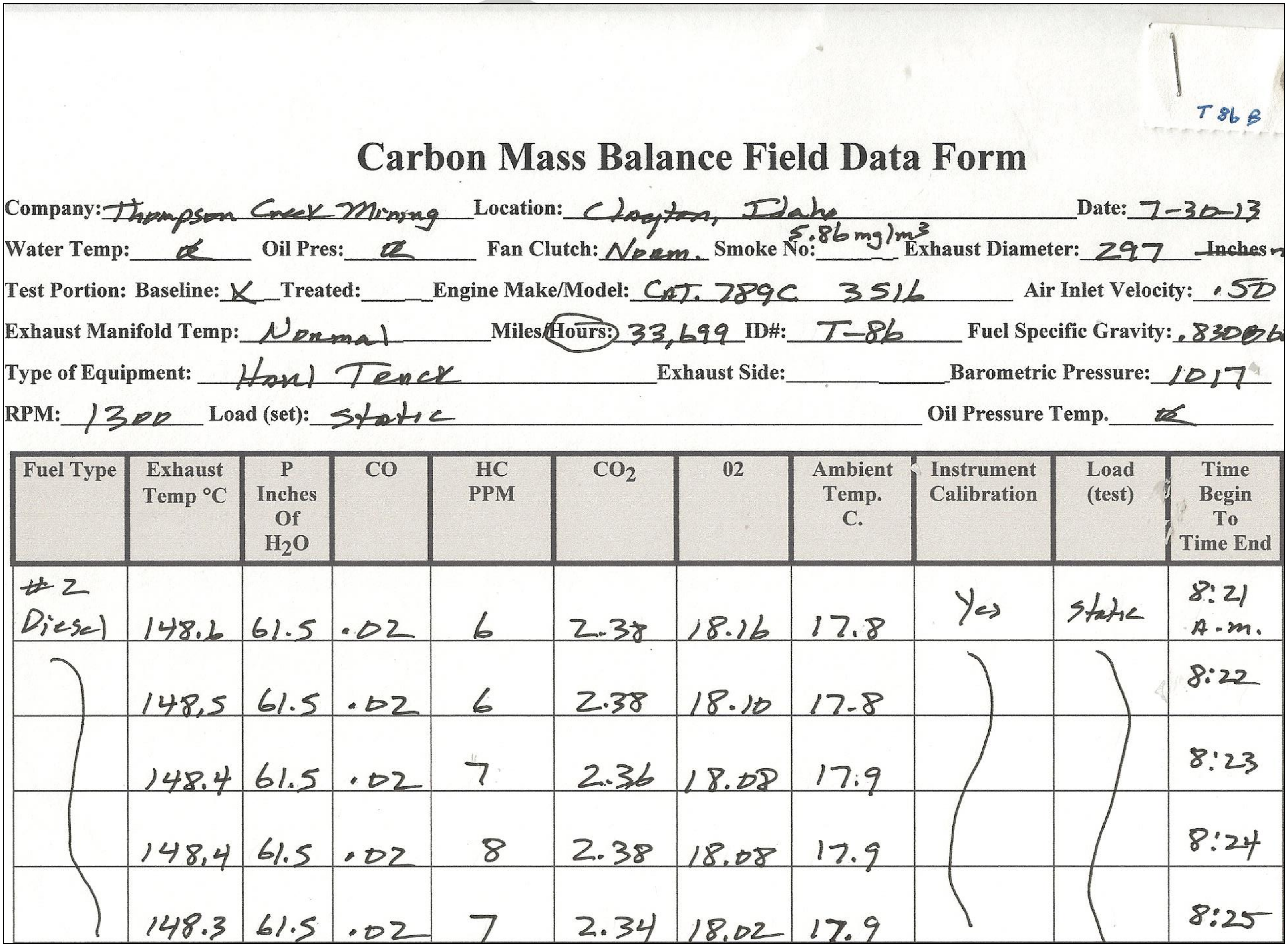
Test Portion: Baseline: ___ **Treated:** X **Engine Make/Model:** CAT. 789C 3516 **Air Inlet Velocity:** .5

Exhaust Manifold Temp: Normal **Miles/Hours:** 45,096 **ID#:** T-80 **Fuel Specific Gravity:** .830@60°F

Type of Equipment: Haul Truck **Exhaust Side:** Top **Barometric Pressure:** 1018

RPM: 1300 **Load (set):** Static **Oil Pressure Temp.** 0

Fuel Type	Exhaust Temp °C	P Inches Of H_2O	CO	HC PPM	CO_2	02	Ambient Temp. C.	Instrument Calibration	Load (test)	Time Begin To Time End
#2 Diesel	149.2	62.25	.02	6	2.46	17.40	13.4	Yes	Static	9:18 A.m.
	149.1	62.25	.02	7	2.44	17.44	13.4			9:19
	149.0	62.25	.02	6	2.42	17.40	13.4			9:20
	149.1	62.25	.02	7	2.44	17.46	13.6			9:21
	149.0	62.25	.02	7	2.42	17.44	13.6			9:22



T 86 B

Carbon Mass Balance Field Data Form

Company: Thompson Creek Mining Location: Clayton, Idaho Date: 7-30-13

Water Temp: 0 Oil Pres: 0 Fan Clutch: Norm. Smoke No: 5.86 mg/m³ Exhaust Diameter: 297 ~~Inches~~ m

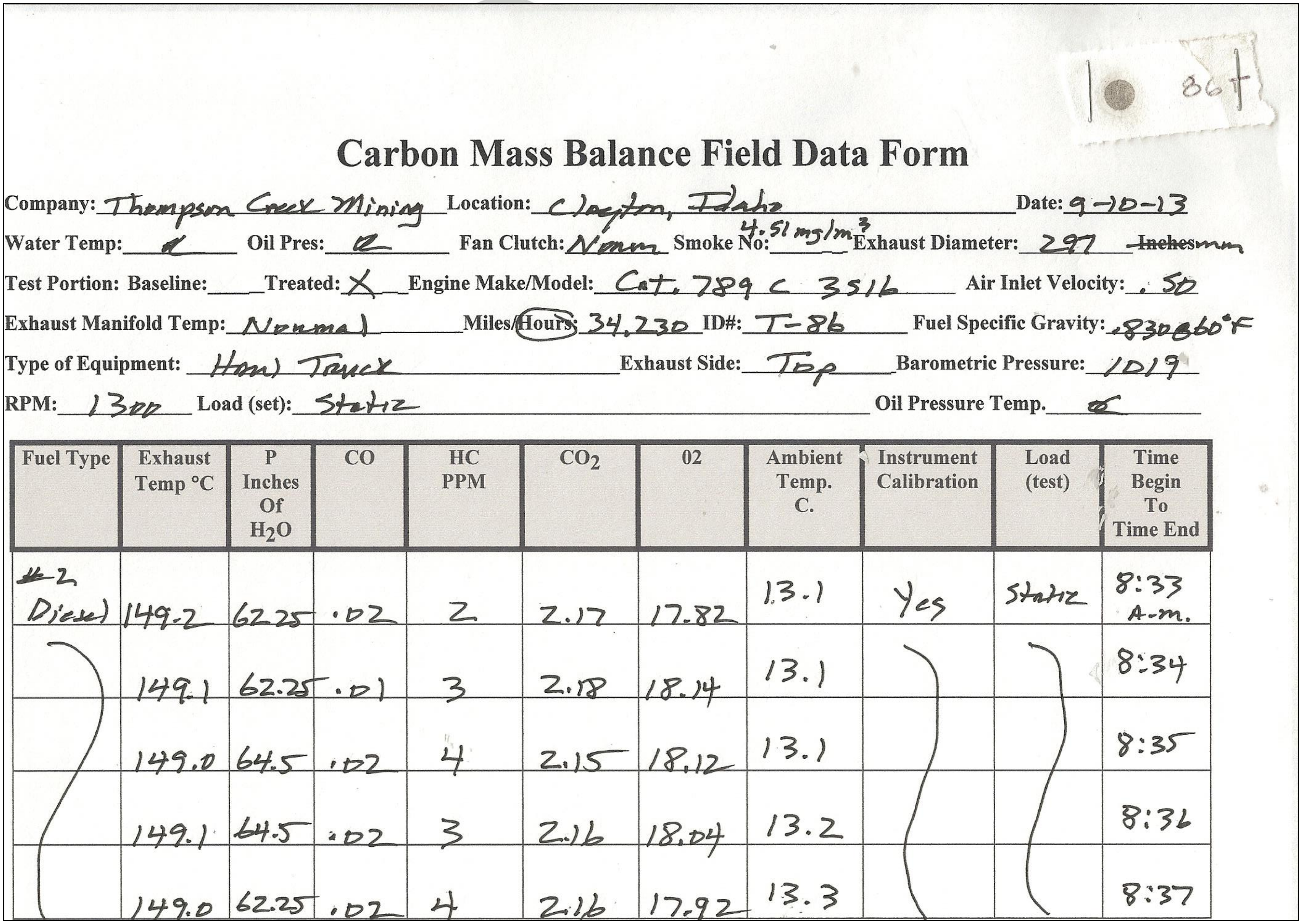
Test Portion: Baseline: X Treated: ____ Engine Make/Model: CAT. 789C 3516 Air Inlet Velocity: .50

Exhaust Manifold Temp: Normal Miles/[✓ Hours]: 33,699 ID#: T-86 Fuel Specific Gravity: .8300b

Type of Equipment: Haul Truck Exhaust Side: ____ Barometric Pressure: 1017

RPM: 1300 Load (set): Static Oil Pressure Temp. 0

Fuel Type	Exhaust Temp °C	P Inches Of H_2O	CO	HC PPM	CO_2	02	Ambient Temp. C.	Instrument Calibration	Load (test)	Time Begin To Time End
#2 Diesel	148.6	61.5	.02	6	2.38	18.16	17.8	Yes	Static	8:21 A.m.
	148.5	61.5	.02	6	2.38	18.10	17.8			8:22
	148.4	61.5	.02	7	2.36	18.08	17.9			8:23
	148.4	61.5	.02	8	2.38	18.08	17.9			8:24
	148.3	61.5	.02	7	2.34	18.02	17.9			8:25



86T

Carbon Mass Balance Field Data Form

Company: Thompson Creek Mining **Location:** Clayton, Idaho **Date:** 9-10-13

Water Temp: 0 **Oil Pres:** 0 **Fan Clutch:** Norm **Smoke No:** 4.51 mg/m3 **Exhaust Diameter:** 297 ~~Inches~~ mm

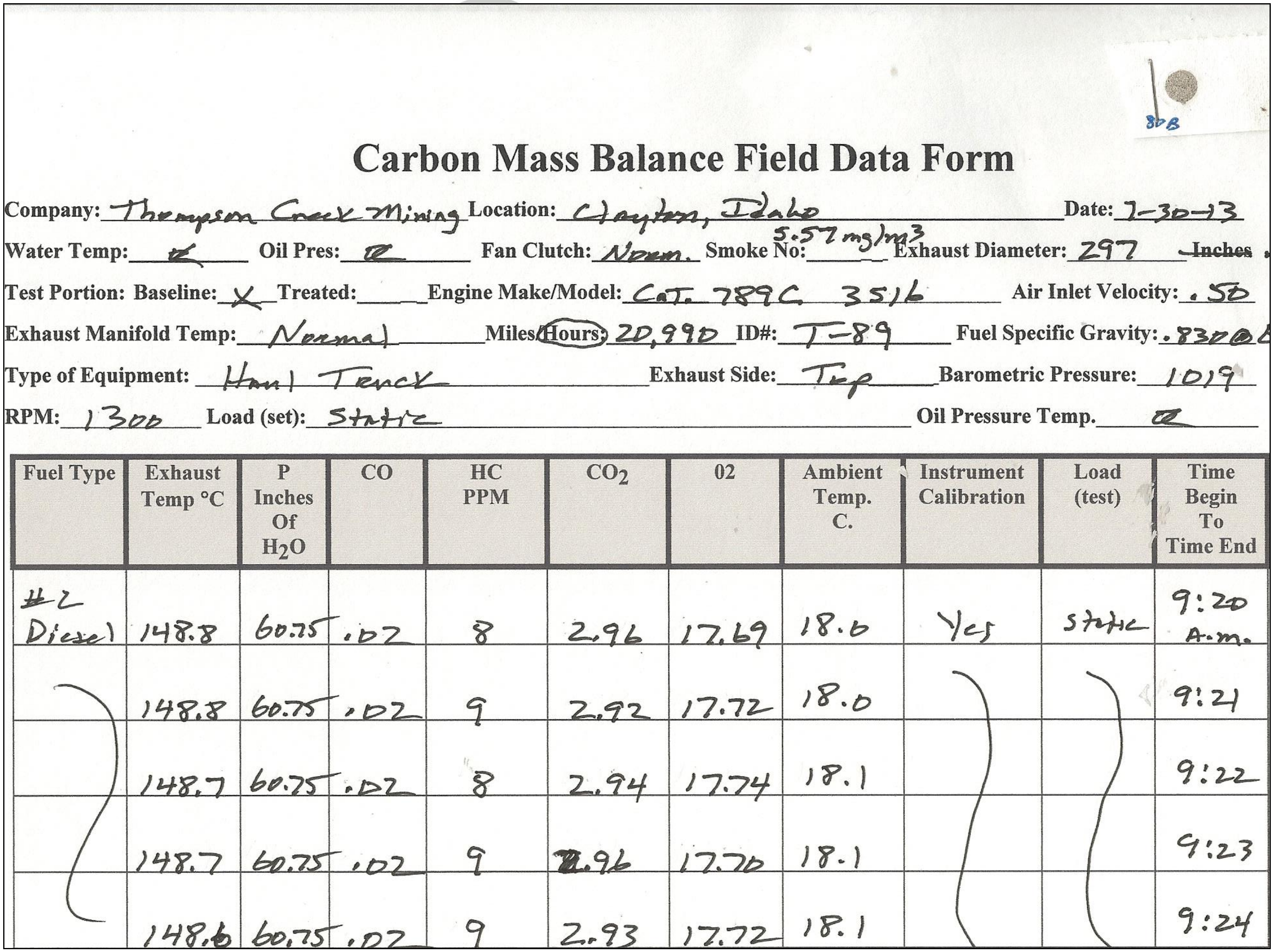
Test Portion: Baseline: ____ **Treated:** X **Engine Make/Model:** Cat. 789 C 3516 **Air Inlet Velocity:** .50

Exhaust Manifold Temp: Normal **Miles/[✓ Hours]:** 34,230 **ID#:** T-86 **Fuel Specific Gravity:** .830 @ 60°F

Type of Equipment: Haul Truck **Exhaust Side:** Top **Barometric Pressure:** 1019

RPM: 1300 **Load (set):** Static **Oil Pressure Temp.** 0

Fuel Type	Exhaust Temp °C	P Inches Of H_2O	CO	HC PPM	CO_2	02	Ambient Temp. C.	Instrument Calibration	Load (test)	Time Begin To Time End
#2 Diesel	149.2	62.25	.02	2	2.17	17.82	13.1	Yes	Static	8:33 A.m.
	149.1	62.25	.01	3	2.18	18.14	13.1			8:34
	149.0	64.5	.02	4	2.15	18.12	13.1			8:35
	149.1	64.5	.02	3	2.16	18.04	13.2			8:36
	149.0	62.25	.02	4	2.16	17.92	13.3			8:37



80B

Carbon Mass Balance Field Data Form

Company: Thompson Creek Mining Location: Clayton, Idaho Date: 7-30-13

Water Temp: 0 Oil Pres: 0 Fan Clutch: Norm. Smoke No: 5.57 mg/m3 Exhaust Diameter: 297 ~~Inches~~

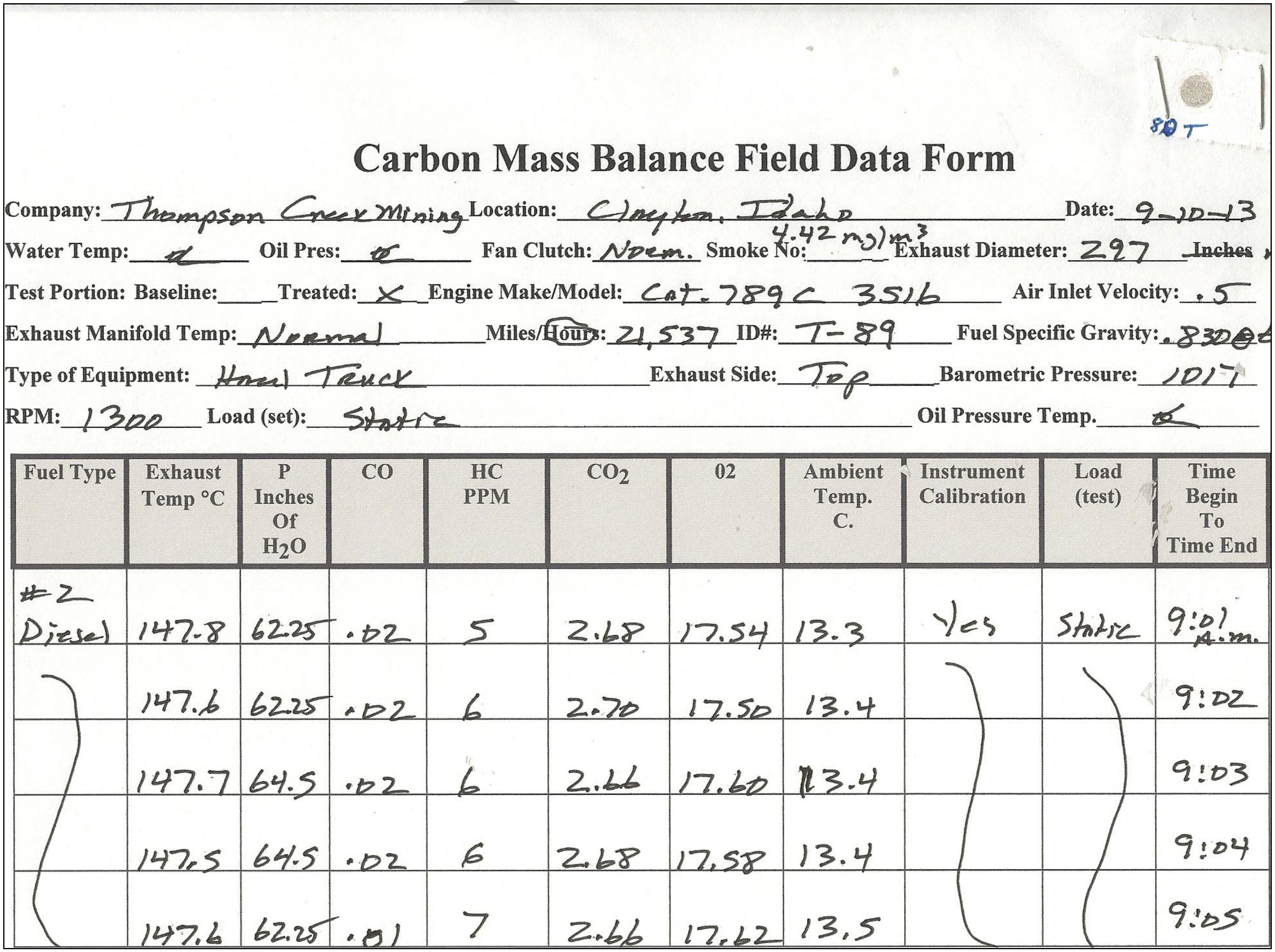
Test Portion: Baseline: X Treated: ___ Engine Make/Model: CAT. 789C 3516 Air Inlet Velocity: .50

Exhaust Manifold Temp: Normal Miles/[✓ Hours]: 20,990 ID#: T-89 Fuel Specific Gravity: .830@

Type of Equipment: Haul Truck Exhaust Side: Top Barometric Pressure: 1019

RPM: 1300 Load (set): Static Oil Pressure Temp. 0

Fuel Type	Exhaust Temp °C	P Inches Of H_2O	CO	HC PPM	CO_2	02	Ambient Temp. C.	Instrument Calibration	Load (test)	Time Begin To Time End
#2 Diesel	148.8	60.75	.02	8	2.96	17.69	18.0	Yes	Static	9:20 A.m.
	148.8	60.75	.02	9	2.92	17.72	18.0			9:21
	148.7	60.75	.02	8	2.94	17.74	18.1			9:22
	148.7	60.75	.02	9	2.96	17.70	18.1			9:23
	148.6	60.75	.02	9	2.93	17.72	18.1			9:24



80 T

Carbon Mass Balance Field Data Form

Company: Thompson Creek Mining Location: Clayton, Idaho Date: 9-10-13

Water Temp: 0 Oil Pres: 0 Fan Clutch: Norm. Smoke No: 4.42 mg/m3 Exhaust Diameter: 297 ~~Inches~~

Test Portion: Baseline: ___ Treated: X Engine Make/Model: Cat. 789C 3516 Air Inlet Velocity: .5

Exhaust Manifold Temp: Normal Miles/[✓ Hours]: 21,537 ID#: T-89 Fuel Specific Gravity: .830

Type of Equipment: Haul Truck Exhaust Side: Top Barometric Pressure: 1017

RPM: 1300 Load (set): Static Oil Pressure Temp. 0

Fuel Type	Exhaust Temp °C	P Inches Of H_2O	CO	HC PPM	CO_2	02	Ambient Temp. C.	Instrument Calibration	Load (test)	Time Begin To Time End
#2 Diesel	147.8	62.25	.02	5	2.68	17.54	13.3	Yes	Static	9:01 A.m.
	147.6	62.25	.02	6	2.70	17.50	13.4			9:02
	147.7	64.5	.02	6	2.66	17.60	13.4			9:03
	147.5	64.5	.02	6	2.68	17.58	13.4			9:04
	147.6	62.25	.01	7	2.66	17.62	13.5			9:05

Appendix IV

Carbon Footprint Data

EMISSIONS & ENVIRONMENTAL

All calculations are estimates only and are not based on actual fuel consumption:

Calculation of Greenhouse Gas Reductions

Assumptions: **Fleet Average (Estimate)**

* Fuel Type = Diesel
*Annual Fuel Usage = 2,500,000 gallons, or 9,500,000 liters.
*Average 7.23% reduction in fuel usage utilizing the FFX fuel catalyst.

Discussion:

When fuel containing carbon is burned in an engine, there are emissions of carbon dioxide (CO_2, methane (CH_4), nitrous oxide (N_20), oxides of nitrogen (NO_x), carbon monoxide (CO), non methane volatile organic compounds (NMVOC's) and sulfur dioxide (SO_2). The amount of each gas emitted depends on the type and quantity of fuel used (the "activity"), the type of combustion equipment, the emissions control technology, and the operating conditions.

The International Greenhouse Partnerships Office section of the Federal Government Department of Science Industry and Technology has produced a workbook outlining how to calculate the quantities of greenhouse gas emissions (see Workbook attached) and is accepted internationally as the accepted approach. The workbook illustrates an example of how to calculate the mass of CO_2 for example on page 21, Table 3.1 and Example 3.1:

> The CO_2 produced from burning 100 litres of diesel oil is calculated as follows:
>
> * the CO_2 emitted if the fuel is completely burned is 2.716 kg CO2/litre (see Appendix A, Table A1)
>
> * the oxidation factor for oil-derived fuels is 99% (see Table 3.1)
> Therefore, the CO_2 produced from burning 100 litres of fuel is:
>
> 100 litres x 2.716 kg CO_2/litre x .99 = 268.88 kg

EMISSIONS & ENVIRONMENTAL

Based on the above calculations, the Greenhouse gas reductions for C02 are as follows:

Test Data Basis	Fuel Usage Litres	kg CO_2 per litre fuel	Oxidation Factor	System CO_2 kg	System CO_2 tonnes
"Baseline"	9,500,000	2.716	0.99	25,543,980	25,544
"Treated"	8,813,150	2.716	0.99	23,697,150	23,697
C02 reductions with FFX catalyst				**1,846, 830**	**1,847**

The reduction of C02 greenhouse emissions in the amount of 1,847 tonnes (2,036 tons) is substantial. Carbon Dioxide accounts for approximately 99.6% of the total greenhouse gas emissions produced. In other words, when diesel oil is burned in an internal combustion engine, the CH4 and N20 emissions contribute less than 0.4% of the greenhouse emissions. This low level is typical of most fossil fuel combustion systems and often is not calculated.

However, by way of additional information, the reduction in CH_4 and $N_2$0 are calculated as follows:

CH_4 Emissions Reduction

* the specific energy content of the fuel is 36.7 MJ/liter (see Table A1), so the total energy in 100 litres is 3,670 MJ, or 3.67 GJ

* the CH_4 emissions factor for diesel oil used in an internal combustion engine is 4.0 g/GJ (see Table A2) so the total CH_4 emitted is 3.67 x 4 = 18.0g

"Baseline" [18.0g/100 liters] x [9,500,000] x [1kg/1000g] = 1.710 kg

"Treated" [18.0g/100 liters] x [8,813,150] x [1kg/1000g] = 1.586 kg

CH_4 Reduction = .224 kg

N_2O Emissions Reduction

* the N_2O emissions factor for diesel oil used in an internal combustion engine is 1,322 g/GJ so the total N2O emitted is 3.67 x 0.6 = 2.7 g

"Baseline" [2.7g/100 litres] x [9,500,000] x [1kg/1000g] = 256.5 kg

"Treated" [2.7g/100 litres] x [8,813,150] x [1kg/1000g] = 237.96 kg

N_2O Reduction = 18.54 kg

EMISSIONS & ENVIRONMENTAL

Appendix V

Carbon Mass Balance Sample Equation

EMISSIONS & ENVIRONMENTAL

Assumptions: C_8H_{15} and SG = 0.78
Time is Constant
Load is Constant

Data:

Mwt = Molecular Weight
pf_1 = Calculated Performance Factor (baseline)(1)
pf_2 = Calculated Performance Factor (treated)(2)
PF_1 = Performance Factor (adjusted for baseline exhaust mass)(1)
PF_2 = Performance Factor (adjusted for treated exhaust mass)(2)
T = Temperature (°F)
F = Flow (exhaust CFM)
SG = Specific Gravity
F = Volume Fraction

$VFC0_2$ = "reading" ÷ 100
$VF0_2$ = "reading" ÷ 100
VFHC = "reading" ÷ 1,000,000
VFCO = "reading" ÷ 100

Equations:

$$\mathrm{Mwt} = (VFHC)(86)+(VFCO)(28)+(VFCO_2)(44)+(VFO_2)(32)+[(1-VFHC-VFCO-VFO_2-VFCO_2)(28)]$$

$$pf_1 \text{ or } PF_1 = \frac{2952.3 \times \mathrm{Mwt}}{89(VFHC)+13.89(VFCO)+13.89(VFCO_2)}$$

$$PF_1 \text{ or } PF_2 = \frac{pf \times (T+460)}{F}$$

Fuel Economy:
Percent Increase (or Decrease) $= \dfrac{(PF_2 - PF_1) \times 100}{PF_1}$

EMISSIONS & ENVIRONMENTAL

Appendix VI

Extracted Emissions Data

EMISSIONS & ENVIRONMENTAL

The averages for all emissions monitored during the Carbon Mass Balance test procedure are tabulated and included in Table 3. The data for the entirety of the evaluation identified an over-all reduction in carbon emissions. The following table enumerates the emissions reductions by segment and specificity:

Table 3

	HC	C02	C0
Baseline:	7.8 ppm	2.60%	.021%
Treated:	**5.4** ppm	2.38%	.018%
Pct. Change:	**- 31%**	**- 8.5%**	**- 14%**

EMISSIONS & ENVIRONMENTAL