FPC FUEL CATALYST LOADBOX TEST OF NORMALLY ASPIRATED LOCOMOTIVE ENGINES USING THE CARBON MASS BALANCE METHOD FOR DETERMINING FUEL CONSUMPTION BY WISCONSIN CENTRAL TRANSPORTATION

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Abstract

This report documents the effect of Fuel Performance Catalyst (FPC), a combustion catalyst, upon engine efficiency, exhaust smoke, exhaust sparking and carbon buildup when used in normally aspirated (roots blown), EMD engines. The subject of this paper is a loadbox test conducted by Wisconsin Central Transportation on four locomotive engines (2 x SW 1500, and 2 x GP35) with and without FPC. Test engines were run under full load at throttle settings 2, 4, 6, and 8. The results were as follows:

(1) Fuel consumption was reduced 4% to 8%, depending upon throttle setting. The switcher test fleet averaged a 7.53% reduction in fuel consumed with FPC treatment. The GP35 test fleet averaged a 5.55% reduction in fuel consumption.

(2) Exhaust smoke density was reduced 6% to 50%. Smoke density reductions averaged 24.8% in the switcher test fleet, and 17.8% in the GP35 test fleet. Exhaust gases were visibly cleaner.

(3) Exhaust "sparking" and carbon buildup in spark arresters were greatly reduced, evidence of cleaner, more complete combustion, and even greater cost savings through reduced maintenance and increased engine life. Further cost reductions and improved public image through reduced trackside fires and visible pollution reduction are another benefit of FPC fuel treatment.

These benefits are supported by dozens of laboratory tests, including the Southwest Research Institute's (SwRI) test using the Association of American Railroads, Recommended Practice 503 (RP-503). Test results reviewed in this report are those from SwRI, the Western Australia Institute of Technology (WAIT) and several genset operations where specific fuel consumption tests have been possible. These studies verify FPC is most effective when used in engines operating in field applications under transient conditions.

The findings of the Wisconsin Central test of the FPC catalyst agree with the above studies, and with others conducted by several railroads. The Wisconsin Central test is the fourth field study with locomotive engines comparing engine performance and emissions from several identical engines with and without FPC catalyst treated fuel.

1.0 INTRODUCTION

During the period of May 1992 to June 1992 an extensive test program was successfully completed at Southwest Research Institute (SwRI), San Antonio, Texas. The test program determined the effect of a fuel combustion catalyst (designated FPC-1®) upon fuel properties, engine wear, deposit formation, and engine performance. The test procedure conducted by SwRI was the Recommended Practice 503 (RP-503), a procedure authored and recognized by the Association of American Railroads (AAR).

The final phase of the RP-503 is a engine performance test on a full-sized, twelve cylinder, 645E3B EMD locomotive engine. The test engine was operated under steady-state conditions and at maximum horsepower output per unit of fuel consumed (optimum brake specific fuel consumption). Brake specific fuel consumption (bsfc) was reduced 1.74% over baseline diesel fuel when consuming diesel fuel treated with FPC catalyst under these engine conditions [Ref 1].

Combustion experts concluded that the 1.74% improvement in bsfc (improved fuel economy) would translate to improvements **several times greater in engines operated in the field due to the transient nature of field operating conditions** [Ref 6].

Other independent laboratory studies, such as the Varimax engine test conducted by the Western Australia Institute of Technology (WAIT) confirm this conclusion. Tests at varying engine speeds, loads, and injection timing agree with expert opinion. The WAIT test revealed FPC catalyst treated fuel produced greater improvements in bsfc as engine operating conditions deviated from best power and bsfc. Although the WAIT engine was tested under steady-state conditions at each rpm, load, and injection timing, the test conditions more closely reproduced field conditions than do steady-state engine testing [Ref 2].

Further, test data from over a dozen specific fuel consumption (sfc) trials of diesel power generating equipment, agree with the WAIT study. Diesel generators, although not subjected to as severe of conditions as engines in mobile equipment, can be tested in the field at specific loads and rpm. It is also reasonably simple to accurately measure fuel consumption and power output in kilowatts [Ref 3].

The results of the RP-503, WAIT, and stationary genset tests have verified the addition of FPC catalyst to diesel fuel, creates significant fuel savings in high horsepower, medium-speed diesel engines. These also verify greater benefit with catalyst treatment of engines used in more transient applications.

The principle subject of this paper is a loadbox test conducted by **Wisconsin Central Transportation** (WCRR) undertook to determine the effect of FPC catalyst (FPC-2 1/10,000 ratio was used) upon fuel economy and emissions in a fleet of four EMD powered locomotives (2 x SW1500 and 2 x GP35). Several throttle notch positions were selected for the test, and the engine fully loaded in an attempt to create engine conditions most like those experienced under actual operation. The results agree with those obtained in previous field tests, the SwRI study, and support expert opinion about FPC catalyst.

2.0 BACKGROUND

2.1 Diesel Combustion Theory

2.1.1 The Combustion Process

The four-cycle compression-ignition engine employs the conventional four strokes per power cycle of intake, compression, power, and exhaust. The two-cycle engine shortens the number of strokes of the piston by combining the power and exhaust stroke, and the intake and compression stroke.

The air inducted on the intake is either normally aspirated or forced in by the supercharger, while the fuel is injected into the cylinder near the end of the compression stroke. In most diesel engines, the combustion chamber temperature at the end of the compression stroke is approximately 600 degrees C (Celsius). This temperature is dependent upon the compression ratio and the initial air temperature.

Near the end of the compression stroke, fuel is sprayed into the combustion chamber at pressures varying from about 1,200 psi to over 30,000 psi. The injection pressure is governed by engine speed and size, and by the type of combustion chamber and injection system used [Ref 4].

With the commencement of fuel injection, the combustion process is initiated. Each charge of injected fuel experiences several phases in the reaction as follows:

(1) An ignition delay period

(2) A period of rapid combustion

(3) A period of combustion where the remainder of the fuel charge is burned as it is injected.

(4) An after burning period in which the unburned fuel may find oxygen and burn, often times referred to as the tail of combustion.

In following the combustion process and the path of fuel particles, it should be understood that after ignition has occurred, many of these steps will be proceeding at the same time, since the mixture is homogeneous [Ref 5].

2.1.2 The Delay Period

The delay consists of a physical and a chemical delay. The physical delay is required to atomize the fuel, mix it with air, vaporize it, and produce a mixture of fuel vapor and air.

During the chemical delay, preflame oxidation reactions occur in localized regions with temperature increases of 540 to 1100 degrees C. These preflame reactions are initiated by the catalytic effect of wall surfaces, high temperatures, and miscellaneous particles that form the active chain carriers prior to rapid combustion. As the local temperature increases, the fuel vapors begin to crack at an accelerating rate and produce material with high percentages of carbon which become heated to incandescence as local ignition is initiated.

Inflammation develops quickly either by rapid and complete oxidation of the fuel and air or the oxidation of the intermediate products of the chain reactions of the fuel [Ref 5].

2.1.3 The Period of Rapid Combustion

Combustion during the period of rapid combustion is due chiefly to the burning of fuel that has had time to vaporize and mix with air during the delay period. The rate and extent of the burning during this period are closely associated with the length of the delay period and its relation to the injection process.

The relation of the delay on both the rate and extent of pressure rise during this phase, is especially strong when the delay period is shorter than the injection period [Ref 5].

2.1.4 The Third Phase of Combustion

The third phase is the period from maximum pressure to the point where combustion is measurably complete.

When the delay period is longer than the injection period, the third period of combustion will involve only the fuel which has not found the necessary oxygen during the period of rapid combustion. In this case, the combustion rate is limited only by the mixing process. However, even when all the fuel is injected before the end of the delay period, poor injection characteristics can extend the third period well into the power or expansion stroke, causing low output and poor efficiency.

When injection timing is such that the second phase of combustion is complete before the end of injection, some portion of the fuel is injected during the third phase, and the rate of burning will be influenced by the rate of injection, as well as by the mixing rate [Ref 4].

2.1.5 The Final Phase of Combustion

The final phase or tail of combustion continues after the third phase at a diminishing rate as any remaining fuel and oxygen are each consumed. This last stage, and the previous one are characterized by diffusion combustion, with production and combustion of carbon particles and a high rate of heat transfer radiation. This phase occurs well down the expansion stroke, when much of the oxygen has been consumed and combustion temperatures are lower. It is at this stage that smoke and carbon monoxide emissions are formed [Ref 4].

2.1.6 The Ideal Combustion Process

The thermal efficiency of an internal combustion engine, whether spark or compression-ignition, will increase if the combustion time is reduced. Mean effective pressure will be higher, and thus more work can be extracted from the same energy input from combustion. The rate of pressure rise during the period of rapid combustion corresponding to constant volume combustion, should be as rapid as possible without exceeding a certain value.

The fuel remaining after the period of rapid pressure rise should be burned at a rate such as to hold the cylinder pressure constant, at the maximum allowable value, until all the fuel is burned.

2.1.7 The Effects of Operating Conditions on Combustion

With respect to the diesel engine, the combustion rate as well as the rate and extent of pressure rise, depends greatly on the design of the combustion chamber and the injection system. However, injection timing, engine speed, turbulence, compression ratio, fuel-air ratio, spray characteristics, fuel cetane number, and inlet temperature and pressure all effect the combustion rate or flame speed.

A detailed discussion of the impact of these operating conditions on combustion is found in Reference 4.

2.2 Possible Mode of Action of the FPC Combustion Catalyst

2.2.1 Flame Propagation

As previously mentioned, the speed with which the combustion process takes place influences the efficiency of the heat released by the chemical reaction. With greater rates of heat release, it is often possible to transfer more of the heat into useful energy.

The combustion catalyst manufactured by UHI Corporation and distributed by FPC Technology, Inc., is a burn rate modifier dissolved in a solvent carrier. When the combustion catalyst is introduced into a liquid hydrocarbon fuel and combustion begins, the catalyst appears to form propagating centers that initiate multiple flame fronts. These propagating centers in effect increase the thermal conductivity of the fuel-air mixture, since heat transmission through it is more rapid with their presence.

Once combustion has been initiated, it is likely that the iron salt thermally decomposes into ions. The iron ions will promote the formation of free hydrocarbon radicals for the combustion process, due to their electron configuration. Other portions of the molecular aggregate, also form ions providing additional free radicals for the combustion process, as well as, providing kinetic energy to local fuel molecules in excess of their normal activation energy.

If the activation energy of the fuel-air mixture can be decreased, the reaction rate will tend to increase. Similarly, if the concentration of reacting substances and the collision frequency of the molecules can be increased, the reaction rate will increase.

Therefore, the thermal efficiency of an internal combustion engine will increase, if the combustion time is decreased. A shorter combustion time implies greater flame speed. Thus, if a proposed combustion catalyst is to be of any benefit in terms of improving horsepower output and/or decreasing fuel consumption, it must increase flame speed or assist in maintaining flame speed through the third and last phases of combustion.

The completeness of combustion may also be positively affected. If combustion is more complete, more energy is liberated while the flame front traverses through the fuel-air mixture. **Controlled engine tests with FPC catalyst reveal not only increased horsepower output and reduced fuel consumption, but typically reduced unwanted gas and particulate exhaust emissions.**

Further, when engine operating conditions are such that flame speed is slowed, creating greater combustion time losses, the FPC fuel catalyst will recover a greater percentage of those losses. Thus, the catalyst will have a more profound effect upon engines operating in the field, than engines operating in the laboratory.

3.0 TESTING

3.1 The AAR RP-503

In early 1992, UHI Corporation was encouraged by several major railroads to conduct tests with FPC catalyst (FPC-1® 1/5000 ratio was used) at Southwest Research Institute (SwRI) using the Association of American Railroads (AAR), the Recommended Practice 503 (RP-503).

The RP-503 constitutes two screening tests and an engine performance trial. The screening tests include the determination of an additives effect upon fuel properties, engine deposit formation, and engine wear. The final procedure is an engine performance trial conducted in a 12 cylinder, 645E3B EMD locomotive engine.

These studies concluded that FPC catalyst had no measurable effect on the chemical properties of the fuel, nor did it detrimentally impact engine life and deposit formation. The EMD engine also showed a 1.74% improvement in bsfc at a 95% confidence level with FPC catalyst treated fuel [Ref 1].

This is a remarkable improvement given the existing efficiency of this particular engine (37.2% brake thermal efficiency and 0.354 bsfc) and the fact the test engine was run under optimum engine conditions (steady-state, notch 8, 900 rpm). Under these conditions, injection timing is the best match for maximum horsepower and lowest bsfc, and therefore, combustion time losses are minimized. Further, the engine was in like-new condition, and smoke emissions were nil.

These engine test conditions are specified by the AAR since a typical locomotive engine operates 50 to 60% of the time at notch 8. However, the steady-state, maximum horsepower operating conditions tend to minimize the potential for horsepower and bsfc gains [Ref 6].

3.2 The WAIT Study

Studies by the Western Australian Institute of Technology (WAIT) have collected considerable data demonstrating the effect of the FPC catalyst on engine efficiency while operating at varying rpm, load, and injection timing. The test was designed to best illustrate the effects of the combustion catalyst. In addition, the test conditions were meant to relate the effect of the catalyst, to the most commonly altered settings and conditions encountered, during normal field operation of a heavy-duty compression-ignition engine.

The objective of the WAIT study was to analyze the effect of the combustion catalyst on engine brake power and brake specific fuel consumption. In order to considerably broaden the scope of the test program in terms of relevance to simulating true commercial and industrial operating conditions, the following parameters were introduced to be varied accordingly:

(1) Engine speed

(2) Throttle setting

(3) Fuel Injection Timing

(4) The concentration of the catalyst in the diesel fuel

The manner in which each parameter was altered is described below:

* Engine speed in all tests was varied from 1600 rpm to 2400 rpm by increments of 200 rpm.

* Throttle settings were altered alternatively from half throttle to full throttle in the majority of the tests.

* Fuel injection timing was varied from 18 degrees before top dead center (BTDC) to 42 degrees BTDC, in increments of 6 degrees, in specific tests. The standard injection timing was 30 degrees BTDC.

* The concentration of the catalyst in the diesel fuel was altered by employing three different mixing ratios.

* Engine base parameters which were held constant during the entire test program were compression ratio, and valve timing. The compression ratio was 18:1. Valve timing was set to the engine manufacturers' recommended values for diesel as is listed below:

INTAKE VALVE	OPENS 10.8 degrees BTDC
	CLOSES 42.6 degrees ABDC
EXHAUST VALVE	OPENS 7.6 degrees BBDC
	CLOSES 21.6 degrees ATDC
VALVE OVERLAP	= 32.4 degrees

Baseline tests using untreated fuel were conducted at the beginning, middle, and end of the test program to check whether any drift in the engine performance had occurred, due to the introduction of the combustion catalyst [Ref 2].

For all tests conducted in the Varimax engine test program at WAIT, full details of which parameters were altered in each particular test are given on each page of tabulated results in APPENDIX 1.0 (The WAIT Study).

3.2.1 Conclusions for the WAIT Study

The Varimax engine test program has shown quite convincingly the benefits of FPC catalyst in diesel fuel. At the highest catalyst concentration in the fuel, bsfc improvements ranged from 1.71% to 4.99%, with an average improvement of 4.19% at half throttle and low torque, 3.04% at full throttle and high torque, and 2.61% at full throttle and 2400 rpm while varying injection timing from 42 degrees BTDC to 18 degrees BTDC.

3.3 SPECIFIC FUEL CONSUMPTION TRIALS OF DIESEL GENERATORS

For over ten years, the FPC combustion catalyst has been subjected to field trials by dozens of professional engineers representing the interest of the company by whom they are employed. These trials have involved all types of engines under virtually every operating condition imaginable. Generally speaking, these field trials reveal FPC catalyst has greater effect upon engines in mobile equipment than stationary equipment, and high speed engines than medium or low speed engines. These data support the laboratory data mentioned above, and the theory that the catalyst affects flame speed [Ref 3].

For the purposes of this paper, although still much like laboratory engines, only the details of specific fuel consumption studies in diesel generators (gensets) will be given. These tend to be the best controlled field tests available, and the only tests where the measurement of specific fuel consumption (kilowatts/liter) are practical.

3.3.1 Diesel Generator Test Method

Typically, the genset is operated under steady-state conditions and fixed load on baseline fuel while the rate of fuel consumption (liters or gallons) and the power output (kilowatts) are measured. Once a reliable database has been accumulated, the fuel for the gensets is treated with FPC catalyst and the gensets operated as normal from three to five hundred hours. This is known as the preconditioning period, and is allowed due to the considerable data that indicates the catalyst first functions to remove existing engine carbon residue, therefore delaying the achievement of maximum catalyst effectiveness.

Once the engine preconditioning period is completed, the gensets are again tested. The procedure, engine speed, and load are reproduced, with the only deviation being the baseline fuel is now treated with FPC catalyst.

All parameters affecting engine efficiency (intake air temperature, intake pressure, fuel density) are measured and corrections to power output and fuel consumption made.

Some fourteen stationary diesel gensets have been tested in this manner. Engines tested include the following makes:

(1) Blackstone EL8

(2) Caterpillar 3412

(3) Cummins VTA28G3

(4) Detroit 12V and 16V149

(5) EMD L20/645F4B

(6) Mirrlee K8 Major

(7) Ruston

(8) English Electric

3.3.2 Conclusions for the Specific Fuel Consumption Trials of the Diesel Generators

Improvements in specific fuel consumption range from 3.1 to 4.8%, with an average for the entire sample of 3.7%. Reductions in smoke density average 23% for all gensets tested [Ref 3].

3.4 The Wisconsin Central Loadbox Test of Four Roots Blown Engines

Wisconsin Central Transportation conducted studies to determine the effect of FPC-2 on fuel economy and smoke emissions in a fleet of SW1500 and GP35 locomotives. The test also involved long term observation of the claimed "cleaning up" ability of the catalyst. The four test locomotives are powered by either 12 cylinder or 16 cylinder EMD engines. All four engines are normally aspirated (roots blown).

A loadbox was employed to load (full load) the engines. Fuel consumption was measured using both a weigh scale method and an exhaust gas analysis method also utilized by the US-EPA, known as the carbon mass balance (cmb). A Bacharach Smokespot Method was used to determine changes in exhaust smoke density.

All locomotives were tested for fuel consumption using the cmb method. The GP35s were tested at notch settings 2, 4, 6, and 8. The SW1500s were tested at notches 2, 4, and 6. All engines were run at full load at each notch setting.

Also, smoke density readings were taken at idle, 2, 4, 6, and 8 (GP35s) or idle, 2, 4, and 6 (SW1500s), also while at full load.

Units 4009 (GP35) and 1550 (SW1500) were tested using a second method which employed a weigh scale. This procedure was developed by Wisconsin Central to determine the fuel consumption of their engines. The weigh scale method and results will be treated in a separate report.

The locomotives were first tested while using untreated (baseline) number 2 diesel fuel. After the baseline tests, the fuel for the four test locomotives were treated with FPC-2 for approximately eight weeks. At the end of the eight week engine preconditioning period, the cmb and weigh scale tests were repeated at identical load and notch settings. Engine rpm and rack length were also reproduced.

3.4.1 Test Methodology

The test methodology for determining changes in fuel consumption was the "Carbon Mass Balance" (cmb). The cmb method measures the carbon containing products of the combustion process (CO_2, CO, HC) found in the exhaust, rather than directly measuring fuel flow into the engine. The CMB also makes possible the determination of FPC catalyst's effect upon regulated emissions, specifically smoke for the diesel engine.

The cmb uses state-of-the-art, non-dispersive infrared analysis (NDIR) and the measurement of carbon containing exhaust gases to determine fuel consumption indirectly. The method has been central to the EPA Federal Test Procedures (FTP) and Highway Fuel Economy Test (HFET) since 1974, and is internationally recognized. This method has proven to be at least as accurate as more conventional flowmeter or weigh scale methods [Ref 8].

The test was supervised by technical representatives for Wisconsin Central. The exhaust gas data collected during the baseline and treated fuel carbon balance tests are summarized on the attached computer printouts (Appendix 3). From these data, the volume fraction (VF) of each gas is 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 is computed. The pf is finally corrected for exhaust temperature and pressure velocity (exhaust density), intake air pressure (barometric) and fuel density, yielding an 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 3. The PF relates to the length of time required to consume a given volume of fuel, therefore a positive change in PF equates to a reduction in fuel consumption (longer time to consume same amount of fuel at the same load). The cmb formula and legend are found on Figure 1 under Appendix 4. A sample calculation is found on Figure 2, also under Appendix 4 (CMB Formulae).

These formulae were provided for UHI by Dr. Geoffrey J. Germane, Ph.D. Mechanical Engineering, and former Department Chair at Brigham Young University, as the technical approach for the cmb. Dr. Germane's resume is also included in Appendix 5 (Dr. G. J. Germane's Resume').

3.4.2 Correction for Fuel Density

Dr. Germane's formulae assume a fuel density of 0.82 (reference specific gravity for diesel). UHI engineers measure fuel specific gravity (density) by taking samples from the rolling tank on each locomotive. Only the treated fuel rate of fuel consumption or PF (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 made to the treated fuel and shown on the treated fuel computer printouts (Appendix 3 Raw Data Computer Printouts).

3.4.3 Correction for Barometric Pressure.

The barometric pressure is used in the calculation of both the baseline and treated fuel PFs. These pressure readings were obtained from the National Weather Service for the Stevens Point area. The barometric pressures are shown on the computer printouts.

3.4.4 Discussion of Smoke Density

Smoke is a product of incomplete combustion, and as such, is a measure of engine efficiency. Smoke is simply unburned fuel droplets that are exhaust from the engine. Generally speaking, these particles are formed during the late stages of combustion when temperatures have fallen off and oxygen availability is limited. The FPC catalyst improves the oxidation of these fuel droplets, speeding flame front development and extracting more useful energy before the exhaust valve or port opens. More power is generated and smoke emissions are reduced.

Smoke measurements from the engines tested during the baseline and treated fuel tests were 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 completely black filter.

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 catalyst treated fuel. A comparison of the baseline and treated Smoke Numbers (shown on Table 2, Appendix 7) indicate the use of FPC catalyst in the Wisconsin Central locomotives created as much as a 50% reduction in smoke density. Smoke reductions were greater at lower notch settings.

The reduced engine smoking leads to less carbon or soot accumulation on stacks, spark arresters, turbochargers (were applicable), and other critical engine components. Less engine smoke also equates to fewer and smaller soot particles exhausting from the engine. The smaller particles have less mass and therefore, carry less heat, burning out before reaching combustion materials near the tracks. Engine component life and efficiency is also maintained much longer.

3.4.5 Discussion of Anomalies

The results of the cmb test are consistent, and agree with other tests from previous railroad tests. The pattern of change also agrees with tests done by Southwest Research Institute on a MP15 locomotive. These tests show the 645 EMD is most efficient in the middle notch settings (4-7), with efficiency declining at the terminal notch settings.

There were two anomalies in the fourteen tests of the four locomotives. The first appeared at notch 2 on the 4009. Here a 17% change in fuel consumption was observed. This is an obvious anomaly, being over three times greater than the average of the remaining three tests conducted on the 4009.

The second anomaly appears in the test results for the 4006. At notch 8, the 4006 saw a 10.9% reduction in fuel consumption. In this case, the problem appears to be the result of a erroneous exhaust pressure velocity reading. Apparently the actual reading was 9.3 inches of water during the treated test, and not the 9.0 that was recorded. If correct, the change in pressure from 9.0 to 9.3 would correct the PF downward to approximately 7.3%, a percentage change that is more in line with the other test results on the 4006.

The anomalies have been removed from the test sample and are not used in the conclusions for this report.

4.0 CONCLUSIONS

(1) As concluded by Southwest Research, under ideal engine conditions, (best power timing, engine speed, load, and at steady-state) the use of FPC catalyst in a locomotive and/or any other medium speed diesel engine will generate a significant fuel economy improvement of no less than 1.74%.

(2) Tests conducted by another independent laboratory, the Western Australia Institute of Technology (WAIT), on a Varimax engine operated at varying rpm, injection timing, and load verify that 1.74% is a minimum, and that average fuel economy improvements under more transient conditions typically experienced in the field will be several times greater.

(3) The same WAIT study determined that fuel economy gain is increased with increasing catalyst concentration and with engine operation deviating from best power parameters, supporting the theory of the catalyst mode of action.

(4) Although engine operating conditions are less severe for stationary engines than for mobile equipment, specific fuel consumption tests in over a dozen stationary heavy duty diesel generator sets operating in the field confirm the WAIT findings. The addition of FPC catalyst to standard diesel fuel improved fuel economy approximately 3.7% in these studies.

(5) Actual field trials in Wisconsin Central's fleet of four roots blown 645E EMD powered locomotives agree with the above conclusions. Fuel consumption was reduced 4% to 8% with FPC catalyst fuel treatment. Additional benefits include reduced engine smoking, exhaust sparks, and carbon or soot buildup.

(6) These data agree with the conclusions rendered by Dr. Geoffrey J. Germane, Ph.D., Mechanical Engineering and Chairman of the Department of Mechanical Engineering, Brigham Young University, in a letter to Mr. Vernon Markworth, Principal Engineer, Design and Development, Department of Engine Research, Southwest Research Institute, 6 August 1992 [Ref 6].

Other combustion experts, such as Dr. G. K. Sharma, Senior Research Manager, Indian Oil Corporation, with whom the writer of this paper has discussed FPC catalyst benefits, also agree [Ref 7].

5.0 RECOMMENDATIONS

Given the considerable independent laboratory and field data collected verifying the potential for fuel savings by treating diesel fuel with FPC-2, a large fuel consumer can realize a significant net fuel cost savings with FPC-2 fuel treatment. The data document actual fuel savings, after FPC-2 fuel treatment under transient engine operating conditions, will be two to three times or more than the RP-503 results. Combustion experts agree with the comparison between the results of the RP-503 and results seen in engines operated in the field.

Wisconsin Central Transportation can expect to experience fuel savings of approximately 6.5% to 7% with FPC-2 fuel treatment. Exact dollar savings will depend upon the cost and volume of fuel used by Wisconsin Central, and the work regime of the engines. Therefore, UHI and Lakeside Oil recommend Wisconsin Central commence fuel treatment with FPC-2 as soon as possible, and begin now to recover the losses being sustained from consuming untreated fuel.

It is also recommended that, upon system wide fuel treatment, a program be initiated to determine the impact of FPC-2 upon long term engine maintenance and engine life. UHI recommends analysis of oil to determine the impact of FPC-2 upon oil viscosity and wear metals. Oil analysis and engine examination have proven the use of FPC catalyst improves lubricant life, reduces engine wear metals (iron and copper), and reduces carbon residue related maintenance and engine failures, particularly pertaining to valves, injectors, ring zone areas, and bearings. Field studies have also documented engine smoking and stack fires are reduced after FPC catalyst fuel treatment.

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8. SAE PAPER, 75302; by Bruce Simpson, Ford Motor Company.

7.0 **<u>APPENDIX 1</u>**

THE "WAIT" STUDY

Comparison of Test Data From The W.A.I.T. Study

Table 1. Change in BSFC (kg/kW hr) at Full Throttle, High Torque

RPM	Base BSFC	FPC-1 BSFC	% Change
1600	0.399	0.389	- 2.51
1800	0.406	0.398	- 1.97
2000	0.417	0.405	- 2.88
2200	0.437	0.420	- 3.89
2400	0.475	0.460	- 3.16
Average:	0.427	0.414	- 3.04

Table 2. Change in BSFC (kg/kW hr) at Half Throttle, Low Torque

RPM	Base BSFC	FPC-1 BSFC	% Change
1600	0.441	0.419	- 4.99
1800	0.441	0.421	- 4.54
2000	0.452	0.437	- 3.32
2200	0.500	0.481	- 3.80
2400	0.552	0.530	- 4.50
Average:	0.477	0.457	- 4.19

Comparison of Test Data From The W.A.I.T. Study

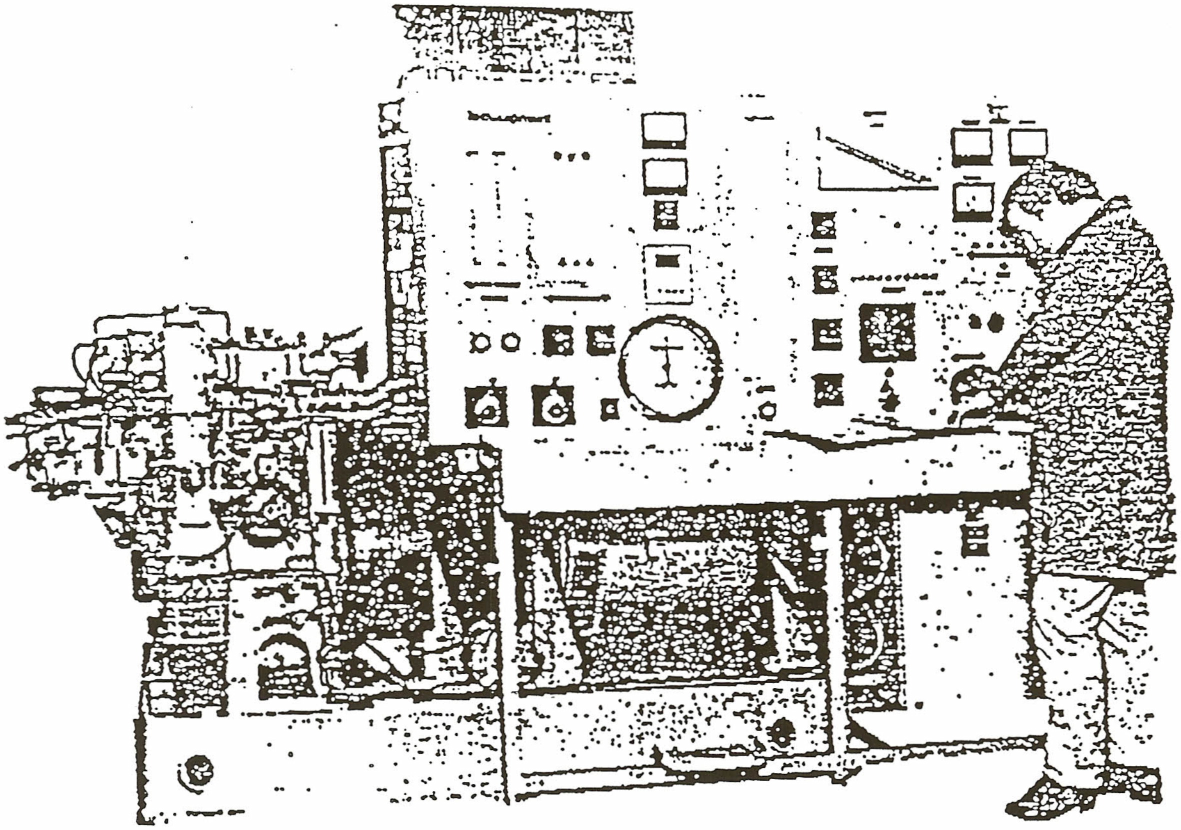
Table 3. Change in BSFC (kg/kW hr) at Full Throttle, 2400 RPM at Optimum Mixing Ratio

BTDC	Base BSFC	FPC-1 BSFC	% Change
42 deg	0.448	0.440	- 1.79
36 deg	0.442	0.434	- 1.81
30 deg	0.469	0.461	- 1.71
24 deg	0.506	0.490	- 3.16
18 deg	0.630	0.608	- 3.49
Average:	0.499	0.486	- 2.61

8.0 **APPENDIX 2**

VARIMAX VARIABLE COMPARISON TEST & RESEARCH RIG

TD35 Varimax Test and Research Engine Rig



Features

Designed specially for teaching and research purposes
Simultaneous study of dynamics and thermodynamics of the internal combustion engine
A robust engine with advanced and unique features
Variable Compression Ratio 4,5:1 to 20:1 whilst engine is running
Petrol/diesel operation with minimal change-over time
Valve timing and opening period adjustable whilst the engine is running
Strain gauged crankshaft suspension system allows analysis of gas and dynamic forces
Transducers indicate cylinder pressure, diesel fuel line pressure, injector needle lift, and flywheel cyclic variations
Mixture strength can be controlled manually with different carburettor chokes supplied
Diesel injection timing may be varied
Spark timing may be varied
Mass of the flywheel can be altered by inertia ring addition
Basic engine, dynamometer motor, and electrical loading unit designed to accept supercharging
Fully integrated test rig complete with instrumentation
Separate cooling circuits for cylinder head and cylinder jacket
Package units for supercharging, petrol injection and operation on natural gas and LPG fuel are available as optional extras

Description

The Varimax Engine Test Rig was designed and developed specially as a teaching unit and for the evaluation of the effects on engine performance of certain fundamental variables. This makes it an invaluable tool for research workers, university lecturers and students.

The engine is a four-stroke, vertical single cylinder, water cooled diesel/petrol unit, nominally rated at 7.6kW (10bhp) with speed variation between 500 and 3000rev/min. The compression ratio can be adjusted between 4.5:1 and 20:1 by raising or lowering the complete crankshaft assembly which is carried in a cradle pivoted on an axis parallel with the crankshaft. Suspension members for carrying this cradle project through the crankcase to anchor points. These members have prepared surfaces to which are attached strain gauges for determining the vertical and horizontal components of the forces acting on the main bearings.

The cast iron cylinder head houses overhead camshafts which are chain driven from the crankshaft. A compensating linkage ensures that there is no phase shift of the camshafts as the crankshaft is raised and lowered.

It is possible to vary the timing and the period for both inlet and exhaust valves whilst the engine is running. These variables are quite independent of each other. Alternatively the valve mechanism may be locked at set values.

The cylinder head is provided with three similar apertures suitable for receiving sparking plugs or pressure transducers, or a fuel injector when operating as a compression ignition engine.

The aluminium piston has one oil scraper and three compression rings.

Ignition is by means of a magneto, driven from one of the half-speed drives. Spark timing is fully adjustable.

A separate cold water make up supply to the mixing tank enables temperatures across the engine to be stabilized during test.

A limit switch short circuits the magneto at compression ratios in excess of 13:1 and, in the event of the engine overspeeding, actuates a solenoid to automatically cut off the fuel supply when running as a diesel engine.

The normal carburettor fitted is a down-draught type supplied with a variety of chokes and an adjustable metering jet.

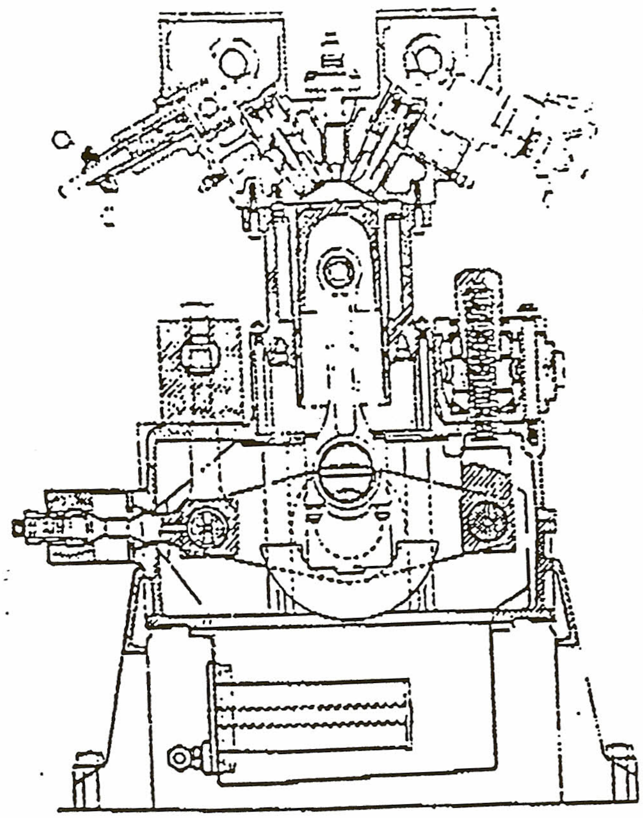
A motor driven pump circulates cooling water through the cylinder head and the cylinder liner jacket, as two separate systems. The flow through each system can be controlled independently and measured.

Crankshaft, camshaft and cradle bearings are all pressure lubricated from a motor driven oil pump. All pipes are BSS colour coded, but a section is in semi-transparent nylon to reveal oil flow.

A crank angle timing disc is provided.

The moment of inertia of the flywheel can be increased by the addition of an inertia ring.

The engine is connected to a trunnion mounted dc swinging field dynamometer through a shaft with flexible universal couplings at each end.



SECTION THROUGH ENGINE

Electrical loading unit

An adjacent framework houses the electrical loading unit. A number of resistance mats in parallel provide 40 equal increments of load. A field regulator provides fine adjustment between each step.

A separate circuit enables the engine to be motored for both starting and determination of friction horse power.

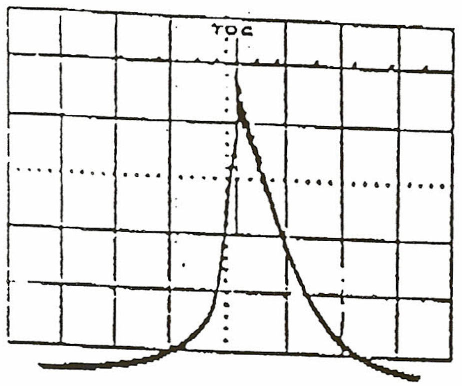
A dc supply of 50 amps at 220V is required for starting purposes, and also provides the generator field excitation. If no such supply is available suitable rectifier cubicle can be quoted for as an extra on request. (Item TD35e).

A single phase ac supply of 15 amps at 200/250V 50/60Hz is also required.

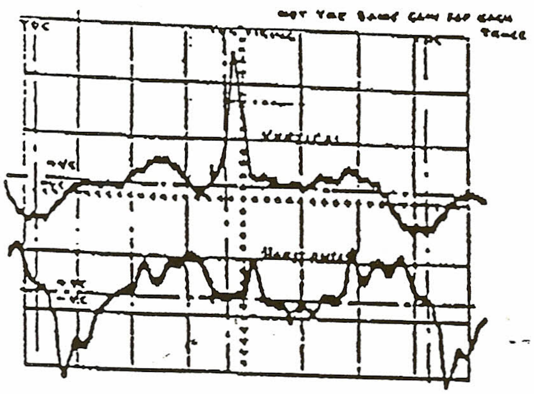
CYLINDER PRESSURE TRACES

1550 rev/min Full throttle 10.5:1 Compression ratio Petrol 96 octane 20° BTDC static ignition 10.7 BHP 87.5 BMEP

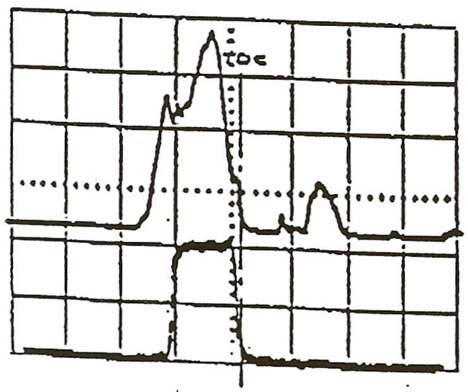
[illegible]



VERTICAL AND HORIZONTAL FORCES



DIESEL FUEL LINE PRESSURE AND NEEDLE LIFT



Range of experiments and performance graphs

Suggested experiments and investigations which may be conducted with this engine and for which complete controls and instrumentation are provided are listed below. This list is by no means exhaustive and serves only as a guide for carrying out a number of experiments pertinent to reciprocating internal combustion engine thermodynamics and dynamics. The facilities incorporated in the design enable an extensive range of projects to be carried out.

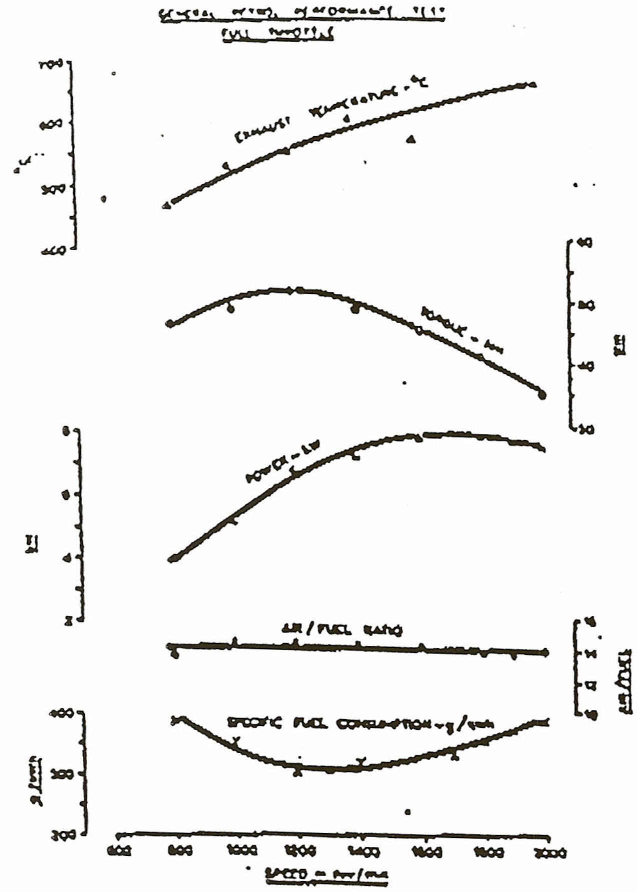
1. Volumetric efficiency – the effect of valve timing. Independent variation of timing and period for inlet and exhaust valves.
2. Measurement of gas and dynamic forces – polar load diagram.
3. Analaysis of cyclic irregularity.
4. Exhaust emission.
5. Measurement of friction and fluid pumping losses.

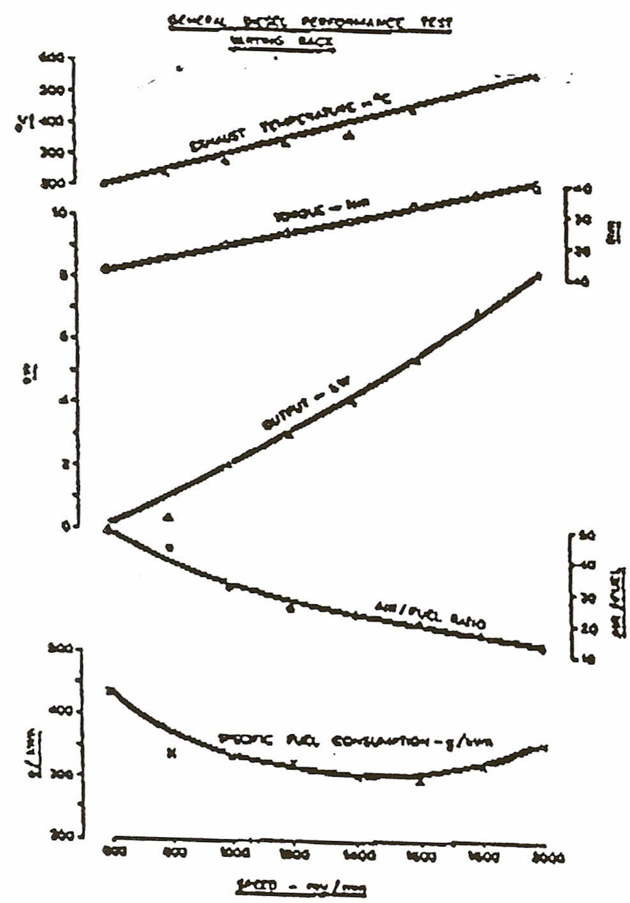
As a spark ignition engine:

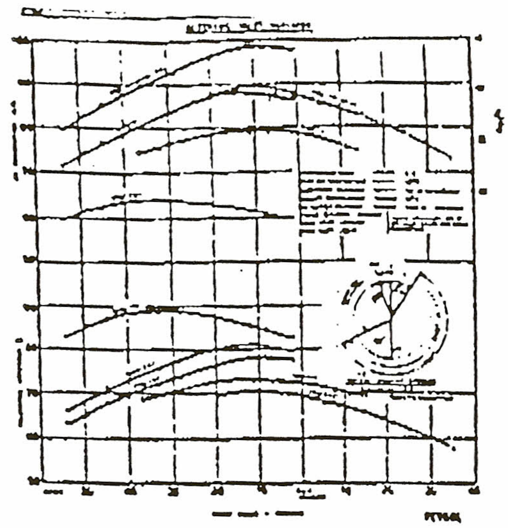
6. Performance characteristic curves of power, specific fuel consumption, etc., over the full speed range.
7. Mixture strength test v thermal efficiency and torque. Also power against air fuel ratio, specific fuel consumption, exhaust temperature.
8. Effect of variable compression ratio on power and thermal efficiency. Also detonation and pre-ignition.
9. Variation of ignition timing – relationship with speed for maximum power developed.
10. Detonation and Octane rating.

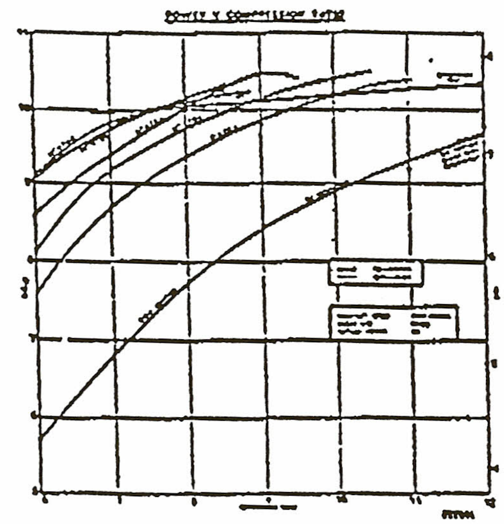
As a compression ignition engine:

11. Performance characteristic curves
12. Effect of variable compression ratio at selected injection timings.
13. Variation of injection timing.
14. Fuel injection equipment studies – needle lift and fuel line pressure can be displayed.









Engine specification

Bore: 95.25mm(3.75in).
Stroke: 114.3mm(4.5in).
rev/min: 500-3000.
Nominal power: 7.5kW(10bhp).
Compression ratio: 4.5:1 to 20:1.

Optional extra

TD35a Mk II Electronics Control Panel.
TD35b Supercharger and associated equipment.
TD35c Petrol Injection Equipment.
TD35d Natural gas and LPG fuel equipment.
TD35e Rectifier Unit to provide 220V 50A dc supply from 3 phase ac supply (voltage and frequency to be specified by the customer at the enquiry stage).

Space required

For free access around the engine test bed an area of 3960mm(156in) by 2540mm(100in) is required. The electronic control panel is a separate unit which should be positioned conveniently close to the engine.

Installation

The rig is free standing on anti-vibration pads, and may readily be moved to any other suitable site if desired.

A 2m(6ft) length of flexible exhaust pipe is provided together with a suitable silencer.

Services required

dc supply. 220V 50A short term rating (starting only). Single phase ac supply 15A at 200/250V. 50/60Hz.

Mains or tank water supply for cooling water make-up.

Drainage for hot water overflow.

Exhaust extension.

It is essential that the engine baseplate is mounted on a well supported concrete foundation.

Dimensions and weights

Nett: 2740mm(108in) x 1295mm(51in) x 1850mm(73in): 1620kg(3584lb)
Gross: (approx — packed for export) 8.43m³(300ft³): 2444kg(5376lb)

Tender specification

To comprise a fully integrated test rig complete with instrumentation to allow a simultaneous study of dynamics and thermodynamics of internal combustion engines. The unit should have a variable compression ratio, variable between 4.5:1 and 20:1 whilst the engine is running. Valve timing and opening period should be adjustable whilst engine is running and the engine should capable of petrol or diesel operation. The time of diesel injection spark should be variable and the crank shaft suspension system should be strain gauged to allow the analysis of gas dynamic forces. Transducers should be filled to allow implication of cylinder pressure, diesel fuel line pressure, injector needle lift, flywheel cyclic variations, in addition the mass of the flywheel should be variable by an inertia ring addition. A separate cooling circuit for cylinder head and cylinder jacket should be incorporated and package unit should be available for super charging, petrol injection and operation on natural gas, and LPG.

9.0 <u>**APPENDIX 3**</u>

RAW DATA COMPUTER PRINTOUTS

Test Portion:	Baseline	*Stack Diam.*	12	Inches		
Engine Type:	EMD-12 Cyl	*Mile/Hrs*				
Equipment Type:	SW 1500	*ID #:*	1550		*Baro*	29.86
Fuel Sp. Gravity(SG	.853	*Temp:*	65			
					Time:	8:20 p.m.

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2	267.4	1.8	0.01	17	1.51	18.7	
2	268.6	1.8	0.01	17	1.51	18.8	
2	268.8	1.6	0.01	15	1.46	18.8	
2	269	1.6	0.01	15	1.46	18.8	
2	269.6	1.6	0.01	15	1.5	18.8	
2.000	**268.680**	**1.680**	**.010**	**15.800**	**1.488**	**18.780**	Mean
0	**.807**	**.110**	**.000**	**1.095**	**.026**	**.045**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.58E-05	0.0001	.015	.188	28.990	428,961	65,302

Company Name:	Wisc.-Central	*Location:*	Stevens Point		*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	12	Inches		
Engine Type:	EMD-12 Cyl	*Mile/Hrs:*				
Equipment Type	SW 1500	*ID #:*	1550		*Baro:*	29.96
Fuel Sp. Gravity:	.853	*Temp:*	57			
SG Corr Factor:	1.000				*Time:*	8:15

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2	251.8	1.6	0.01	13	1.43	19	
2	254.2	1.6	0.01	15	1.45	19.1	
2	253	1.6	0.01	13	1.4	19.3	
2	253.4	1.5	0.01	13	1.38	19.3	
2	256	1.5	0.01	13	1.41	19.3	
2.000	**253.680**	**1.560**	**.010**	**13.400**	**1.414**	**19.200**	Mean
0	**1.559**	**.055**	**.000**	**.894**	**.027**	**.141**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
1.34E-05	0.0001	.014	.192	28.995	451,654	70,732

Performance factor adjusted for fuel density: 70,732

****% Change PF= 8.32 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Test Portion:	Baseline	*Stack Diam.*	12	Inches	
Engine Type:	EMD-12 Cyl	*Mile/Hrs*			
Equipment Type:	SW 1500	*ID #:*	1550	*Baro*	29.86
Fuel Sp. Gravity(SG	.853	*Temp:*	65		
				Time:	8:20 p.m.

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
4	477.6	4.6	0.02	18	3.48	16.4	
4	481.2	4.6	0.02	18	3.48	16.4	
4	486.6	4.6	0.02	18	3.51	16.3	
4	489.2	4.6	0.02	18	3.5	16.3	
4	491.8	4.6	0.02	18	3.49	16.3	
4.000	**485.280**	**4.600**	**.020**	**18.000**	**3.492**	**16.340**	Mean
0	**5.815**	**.000**	**.000**	**.000**	**.013**	**.055**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.80E-05	0.0002	.035	.163	29.213	185,015	19,387

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	12	Inches	
Engine Type:	EMD-12 Cyl	*Mile/Hrs:*			
Equipment Type	SW 1500	*ID #:*	1550	*Baro:*	29.96
Fuel Sp. Gravity:	.853	*Temp:*	57		
SG Corr Factor:	1.000			*Time:*	8:15

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
4	480.6	4.4	0.01	13	3.4	17.3	
4	483.4	4.4	0.01	13	3.38	17.2	
4	487	4.4	0.01	17	3.34	17.3	
4	485	4.3	0.01	17	3.31	17.3	
4	486.6	4.3	0.01	17	3.33	17.3	
4.000	**484.520**	**4.360**	**.010**	**15.400**	**3.352**	**17.280**	Mean
0	**2.614**	**.055**	**.000**	**2.191**	**.037**	**.045**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
1.54E-05	0.0001	.034	.173	29.228	193,436	20,846

Performance factor adjusted for fuel density: 20,846

****% Change PF= 7.53 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Test Portion:	Baseline	*Stack Diam.*	12	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs*			
Equipment Type:	SW 1500	*ID #:*	1550	*Baro*	29.86
Fuel Sp. Gravity(SG	.853	*Temp:*	65		
				Time:	8:20 p.m.

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
6	671.2	7	0.02	23	4.66	14.7	
6	673	7	0.02	23	4.64	14.7	
6	681	7	0.02	22	4.67	14.8	
6	685.4	7	0.02	23	4.63	14.7	
6	687.4	7	0.02	23	4.71	14.7	
6.000	**679.600**	**7.000**	**.020**	**22.800**	**4.662**	**14.720**	Mean
0	**7.255**	**.000**	**.000**	**.447**	**.031**	**.045**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
2.28E-05	0.0002	.047	.147	29.336	139,386	13,000

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	12	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs:*			
Equipment Type	SW 1500	*ID #:*	1550	*Baro:*	29.96
Fuel Sp. Gravity:	.853	*Temp:*	57		
SG Corr Factor:	1.000			*Time:*	8:15

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
6	674.8	6.7	0.03	19	4.44	16	
6	678	6.7	0.02	17	4.41	16	
6	682.6	6.7	0.02	19	4.4	16	
6	685.8	6.7	0.03	19	4.53	15.9	
6	685.4	6.7	0.02	19	4.51	16	
6.000	**681.320**	**6.700**	**.024**	**18.600**	**4.458**	**15.980**	Mean
0	**4.793**	**.000**	**.005**	**.894**	**.059**	**.045**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
1.86E-05	0.00024	.045	.160	29.354	145,760	13,929

Performance factor adjusted for fuel density: 13,929

****% Change PF= 7.15 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/18/96
Test Portion:	Baseline	*Stack Diam.*	12 Inches		
Engine Type:	EMD-12 Cyl	*Mile/Hrs*			
Equipment Type:	SW 1500	*ID #:*	1554	*Baro*	29.83
Fuel Sp. Gravity(SG	.853	*Temp:*	59		
				Time:	8:30 p.m.

Rack	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2	247.6	1.8	0.01	14	1.51	19	
2	247.8	1.8	0.01	14	1.5	19	
2	248.6	1.8	0.01	14	1.5	19	
2	249.6	1.8	0.01	14	1.49	19	
2	250	1.8	0.01	14	1.46	19	
2	**248.720**	**1.800**	**.010**	**14.000**	**1.492**	**19.000**	Mean
0	**1.064**	**.000**	**.000**	**.000**	**.019**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.40E-05	0.0001	.015	.190	29.000	428,290	62,089

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	12 Inches		
Engine Type:	EMD-12 Cyl	*Mile/Hrs:*			
Equipment Type	SW 1500	*ID #:*	1554	*Baro:*	29.91
Fuel Sp. Gravity:	.853	*Temp:*	80		
SG Corr Factor:	1.000			*Time:*	2:30 p.m.

Rack	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2	238	1.7	0.01	15	1.44	19	
2	235.8	1.7	0.01	15	1.4	19	
2	228	1.7	0.01	15	1.38	19.1	
2	227.2	1.7	0.01	15	1.4	19	
2	225.6	1.6	0.01	15	1.42	19	
2.000	**230.920**	**1.680**	**.010**	**15.000**	**1.408**	**19.020**	Mean
0	**5.581**	**.045**	**.000**	**.000**	**.023**	**.045**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
1.50E-05	0.0001	.014	.190	28.987	453,102	67,222

Performance factor adjusted for fuel density: 67,222

****% Change PF= 8.27 %**

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

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Date:*	6/18/96
Test Portion:	Baseline	*Stack Diam.*	12 Inches		
Engine Type:	EMD-12 Cyl	*Mile/Hrs*			
Equipment Type:	SW 1500	*ID #:*	1554	*Baro*	29.83
Fuel Sp. Gravity(SG	.853	*Temp:*	59		
				Time:	8:30 p.m.

Rack	Exh Temp	Pv Inch	CO	HC	CO2	O2	
4	476.8	5	0.01	17	3.86	16.3	
4	487.6	5	0.01	17	3.87	16.2	
4	499	5	0.01	18	3.83	16.2	
4	504.4	5	0.01	18	3.88	16.1	
4	506.2	5	0.01	18	3.83	16.2	
4.000	**494.800**	**5.000**	**.010**	**17.600**	**3.854**	**16.200**	Mean
0	**12.406**	**.000**	**.000**	**.548**	**.023**	**.071**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.76E-05	0.0001	.039	.162	29.266	168,523	17,014

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	12 Inches		
Engine Type:	EMD-12 Cyl	*Mile/Hrs:*			
Equipment Type	SW 1500	*ID #:*	1554	*Baro:*	29.91
Fuel Sp. Gravity:	.853	*Temp:*	80		
SG Corr Factor:	1.000			*Time:*	2:30 p.m.

Rack	Exh Temp	Pv Inch	CO	HC	CO2	O2	
4	482.2	5	0.01	22	3.52	16.6	
4	497.2	5	0.01	22	3.57	16.5	
4	499.6	5	0.01	22	3.68	16.2	
4	502.8	5	0.01	22	3.57	16.5	
4	506.8	5	0.01	22	3.56	16.4	
4.000	**497.720**	**5.000**	**.010**	**22.000**	**3.580**	**16.440**	Mean
0	**9.393**	**.000**	**.000**	**.000**	**.060**	**.152**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
2.20E-05	0.0001	.036	.164	29.232	180,993	18,325

Performance factor adjusted for fuel density: 18,325

****% Change PF= 7.71 %**

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

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Date:*	6/18/96
Test Portion:	Baseline	*Stack Diam.*	12 Inches		
Engine Type:	EMD-12 Cyl	*Mile/Hrs*			
Equipment Type:	SW 1500	*ID #:*	1554	*Baro*	29.83
Fuel Sp. Gravity(SG	.853	*Temp:*	59		
				Time:	8:30 p.m.

Rack	Exh Temp	Pv Inch	CO	HC	CO2	O2	
6	655.6	7.5	0.03	19	5.15	14.3	
6	659.2	7.5	0.03	19	5.16	14.4	
6	642	7.5	0.03	19	5.12	14.4	
6	640.1	7.5	0.03	19	5.1	14.4	
6.000	**649.225**	**7.500**	**.030**	**19.000**	**5.133**	**14.375**	Mean
0	**9.585**	**.000**	**.000**	**.000**	**.028**	**.050**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.90E-05	0.0003	.051	.144	29.397	126,773	11,264

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	12 Inches		
Engine Type:	EMD-12 Cyl	*Mile/Hrs:*			
Equipment Type	SW 1500	*ID #:*	1554	*Baro:*	29.91
Fuel Sp. Gravity:	.853	*Temp:*	80		
SG Corr Factor:	1.000			*Time:*	2:30 p.m.

Rack	Exh Temp	Pv Inch	CO	HC	CO2	O2	
6	620.4	7.2	0.03	28	4.84	14.8	
6	622	7.2	0.03	28	4.86	14.7	
6	612.8	7.2	0.03	28	4.88	15	
6	618.8	7.2	0.03	28	4.88	15	
6	619.6	7.1	0.03	28	4.87	15.1	
6.000	**618.720**	**7.180**	**.030**	**28.000**	**4.866**	**14.920**	Mean
0	**3.515**	**.045**	**.000**	**.000**	**.017**	**.164**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
2.80E-05	0.0003	.049	.149	29.377	133,408	11,963

Performance factor adjusted for fuel density: 11,963

****% Change PF= 6.21 %**

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

Test Portion: Baseline *Stack Diam.* 8 Inches

Engine Type: EMD-16 Cyl *Mile/Hrs*

Equipment Type: GP 35 *ID #:* 4009 *Baro* 29.82

Fuel Sp. Gravity(SG .853 *Temp:* 57

Time: 11:22

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2	276.2	1.6	0.01	14	1.83	18.5	
2	276.4	1.6	0.01	14	1.83	18.5	
2	276.8	1.6	0.01	14	1.83	18.6	
2	277	1.6	0.01	14	1.83	18.6	
2	277.4	1.6	0.01	14	1.83	18.5	
2.000	**276.760**	**1.600**	**.010**	**14.000**	**1.830**	**18.540**	Mean
0	**.477**	**.000**	**.000**	**.000**	**.000**	**.055**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.40E-05	0.0001	.018	.185	29.035	350,428	123,591

Company Name: Wisc.-Central *Location:* Stevens Point *Test Date:* 8/15/96

Test Portion: Treated *Stack Diam:* 8 Inches

Engine Type: EMD-16 Cyl *Mile/Hrs:*

Equipment Type GP 35 *ID #:* 4009 *Baro:* 29.99

Fuel Sp. Gravity: .854 *Temp:* 59

SG Corr Factor: .999 *Time:* 8:15

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2	289	1.65	0.01	15	1.61	19	
2	283.6	1.7	0.01	15	1.51	19	
2	283.6	1.7	0.01	15	1.5	19	
2	283.6	1.7	0.01	15	1.49	19	
2	283.4	1.7	0.01	15	1.51	19	
2.000	**284.640**	**1.690**	**.010**	**15.000**	**1.524**	**19.000**	Mean
0	**2.439**	**.022**	**.000**	**.000**	**.049**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
1.50E-05	0.0001	.015	.190	29.005	419,309	145,072

Performance factor adjusted for fuel density: 144,902

****% Change PF= 17.24 %**

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

Company Name: Wisc.-Central *Location* Stevens Point *Date:* 6/19/96

Test Portion:	Baseline	*Stack Diam.*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs*			
Equipment Type:	GP 35	*ID #:*	4009	*Baro*	29.82
Fuel Sp. Gravity(SG	.853	*Temp:*	57		
				Time:	11:22

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
4	481.4	4	0.02	18	3.84	16.2	
4	487.4	4	0.02	17	3.8	16.2	
4	493.2	4	0.02	17	3.84	16.3	
4	492.8	4	0.01	17	3.83	16.3	
4	495	4	0.02	17	3.81	16.3	
4.000	**489.960**	**4.000**	**.018**	**17.200**	**3.824**	**16.260**	Mean
0	**5.563**	**.000**	**.004**	**.447**	**.018**	**.055**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.72E-05	0.00018	.038	.163	29.263	169,482	42,927

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/15/96
Test Portion:	Treated	*Stack Diam:*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs:*			
Equipment Type	GP 35	*ID #:*	4009	*Baro:*	29.99
Fuel Sp. Gravity:	.854	*Temp:*	59		
SG Corr Factor:	.999			*Time:*	8:15

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
4	508	3.8	0.02	27	3.85	16.3	
4	510	3.7	0.02	27	3.85	16.3	
4	510	3.7	0.02	24	3.84	16.5	
4	511.2	3.7	0.02	26	3.82	16.4	
4	510.8	3.7	0.02	26	3.82	16.4	
4.000	**510.000**	**3.720**	**.020**	**26.000**	**3.836**	**16.380**	Mean
0	**1.233**	**.045**	**.000**	**1.225**	**.015**	**.084**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
2.60E-05	0.0002	.038	.164	29.270	168,665	44,891

Performance factor adjusted for fuel density: 44,838

****% Change PF= 4.45 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Test Portion:	Baseline	*Stack Diam.*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs*			
Equipment Type:	GP 35	*ID #:*	4009	*Baro*	29.82
Fuel Sp. Gravity(SG	.853	*Temp:*	57		
				Time:	11:22

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
6	668.4	7.2	0.1	20	4.92	14.8	
6	672.8	7.2	0.1	21	4.91	14.8	
6	677.6	7.2	0.09	20	4.89	15	
6	678.8	7.2	0.09	21	4.89	15	
6	679.2	7.2	0.09	21	4.92	14.9	
6.000	**675.360**	**7.200**	**.094**	**20.600**	**4.906**	**14.900**	Mean
0	**4.653**	**.000**	**.005**	**.548**	**.015**	**.100**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
2.06E-05	0.00094	.049	.149	29.382	130,789	26,993

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/15/96
Test Portion:	Treated	*Stack Diam:*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs:*			
Equipment Type	GP 35	*ID #:*	4009	*Baro:*	29.99
Fuel Sp. Gravity:	.854	*Temp:*	59		
SG Corr Factor:	.999			*Time:*	8:15

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
6	687.4	6.8	0.09	32	4.89	15.2	
6	689.2	6.8	0.09	32	4.89	15.1	
6	690.8	6.8	0.09	31	4.92	15.2	
6	691.4	6.8	0.09	31	4.92	15.2	
6	692	6.8	0.09	31	4.88	15.2	
6.000	**690.160**	**6.800**	**.090**	**31.400**	**4.900**	**15.180**	Mean
0	**1.862**	**.000**	**.000**	**.548**	**.019**	**.045**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
3.14E-05	0.0009	.049	.152	29.393	130,918	28,064

Performance factor adjusted for fuel density: 28,031

****% Change PF= 3.84 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Test Portion:	Baseline	*Stack Diam.*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs*			
Equipment Type:	GP 35	*ID #:*	4009	*Baro*	29.82
Fuel Sp. Gravity(SG	.853	*Temp:*	57		
				Time:	11:22

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
8	848.8	9.4	0.29	23	5.98	13.2	
8	852.6	9.4	0.28	23	5.93	13.3	
8	853.2	9.2	0.28	23	6.01	13.4	
8	860.2	9.2	0.29	22	6	13.4	
8	857	9.4	0.29	22	5.92	13.5	
8.000	**854.360**	**9.320**	**.286**	**22.600**	**5.968**	**13.360**	Mean
0	**4.371**	**.110**	**.005**	**.548**	**.041**	**.114**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
2.26E-05	0.00286	.060	.134	29.491	104,984	20,491

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/15/96
Test Portion:	Treated	*Stack Diam:*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs:*			
Equipment Type	GP 35	*ID #:*	4009	*Baro:*	29.99
Fuel Sp. Gravity:	.854	*Temp:*	59		
SG Corr Factor:	.999			*Time:*	8:15

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
8	868	9	0.25	44	5.79	14.1	
8	871	9	0.25	44	5.81	13.9	
8	875.2	9	0.26	41	5.75	13.8	
8	877.4	9	0.25	39	5.72	14.1	
8	882	9	0.27	37	5.65	14.2	
8.000	**874.720**	**9.000**	**.256**	**41.000**	**5.744**	**14.020**	Mean
0	**5.464**	**.000**	**.009**	**3.082**	**.063**	**.164**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.10E-05	0.00256	.057	.140	29.482	109,173	21,913

Performance factor adjusted for fuel density: 21,888

****% Change PF= 6.82 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Test Portion:	Baseline	*Stack Diam.*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs*			
Equipment Type:	GP 35	*ID #:*	4006	*Baro*	29.86
Fuel Sp. Gravity(SG	.853	*Temp:*	57		
				Time:	8:35

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2	262.6	1.8	0.02	17	1.51	18.9	
2	264.8	1.9	0.02	17	1.51	18.9	
2	264.8	1.8	0.02	17	1.51	18.9	
2	266.8	1.8	0.02	17	1.47	19	
2.000	**264.750**	**1.825**	**.020**	**17.000**	**1.500**	**18.925**	Mean
0	**1.716**	**.050**	**.000**	**.000**	**.020**	**.050**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.70E-05	0.0002	.015	.189	28.998	422,694	138,537

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs:*			
Equipment Type	GP 35	*ID #:*	4006	*Baro:*	29.95
Fuel Sp. Gravity:	.853	*Temp:*	60		
SG Corr Factor:	1.000			*Time:*	9:45

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2	271	1.6	0.02	18	1.52	18.9	
2	270.4	1.6	0.02	18	1.52	19	
2	273.4	1.6	0.01	17	1.46	19	
2	274	1.6	0.01	17	1.52	19	
2	276.2	1.6	0.02	17	1.46	19	
2.000	**273.000**	**1.600**	**.016**	**17.400**	**1.496**	**18.980**	Mean
0	**2.354**	**.000**	**.005**	**.548**	**.033**	**.045**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
1.74E-05	0.00016	.015	.190	29.000	424,867	149,787

Performance factor adjusted for fuel density: 149,787

****% Change PF= 8.12 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Test Portion:	Baseline	*Stack Diam.*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs*			
Equipment Type:	GP 35	*ID #:*	4006	*Baro*	29.81
Fuel Sp. Gravity(SG	.853	*Temp:*	57		
				Time:	8:35

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
4	484	4.2	0.01	19	3.44	16.7	
4	484.2	4.2	0.01	19	3.43	16.7	
4	483.2	4.2	0.01	19	3.38	16.8	
4	483.2	4.2	0.01	18	3.37	16.8	
4	482.8	4.2	0.01	18	3.35	16.8	
4.000	**483.480**	**4.200**	**.010**	**18.600**	**3.394**	**16.760**	Mean
0	**.593**	**.000**	**.000**	**.548**	**.039**	**.055**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
1.86E-05	0.0001	.034	.168	29.215	190,851	47,005

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs:*			
Equipment Type	GP 35	*ID #:*	4006	*Baro:*	29.95
Fuel Sp. Gravity:	.853	*Temp:*	60		
SG Corr Factor:	1.000			*Time:*	9:45

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
4	513.6	4	0.01	24	3.39	16.7	
4	517.4	4	0.01	24	3.39	16.7	
4	517.4	4	0.01	24	3.39	16.7	
4	517.8	3.8	0.01	25	3.37	16.6	
4	518	3.8	0.01	25	3.36	16.6	
4.000	**516.840**	**3.920**	**.010**	**24.400**	**3.380**	**16.660**	Mean
0	**1.830**	**.110**	**.000**	**.548**	**.014**	**.055**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
2.44E-05	0.0001	.034	.167	29.209	191,389	49,764

Performance factor adjusted for fuel density: 49,764

****% Change PF= 5.87 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Test Portion:	Baseline	*Stack Diam.*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs*			
Equipment Type:	GP 35	*ID #:*	4006	*Baro*	29.81
Fuel Sp. Gravity(SG	.853	*Temp:*	57		
				Time:	8:35

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
6	653.6	7.2	0.03	25	4.56	15.3	
6	655.6	7.2	0.03	24	4.56	15.3	
6	657.6	7.2	0.03	24	4.56	15.2	
6	657.2	7.2	0.03	23	4.56	15.2	
6	658	7.2	0.03	23	4.56	15.3	
6.000	**656.400**	**7.200**	**.030**	**23.800**	**4.560**	**15.260**	Mean
0	**1.811**	**.000**	**.000**	**.837**	**.000**	**.055**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
2.38E-05	0.0003	.046	.153	29.341	142,177	29,093

Company Name:	Wisc.-Central	*Location:*	Stevens Point	*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	8	Inches	
Engine Type:	EMD-16 Cyl	*Mile/Hrs:*			
Equipment Type	GP 35	*ID #:*	4006	*Baro:*	29.95
Fuel Sp. Gravity:	.853	*Temp:*	60		
SG Corr Factor:	1.000			*Time:*	9:45

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
6	691.6	6.8	0.03	28	4.57	15.8	
6	690.6	6.8	0.03	28	4.58	15.7	
6	690.8	6.8	0.03	28	4.56	15.6	
6	691.6	6.8	0.03	29	4.61	15.5	
6	693	6.8	0.03	28	4.6	15.5	
6.000	**691.520**	**6.800**	**.030**	**28.200**	**4.584**	**15.620**	Mean
0	**.944**	**.000**	**.000**	**.447**	**.021**	**.130**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
2.82E-05	0.0003	.046	.156	29.360	141,443	30,317

Performance factor adjusted for fuel density: 30,317

****% Change PF= 4.21** %

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

Test Portion:	Baseline	*Stack Diam.*	8	Inches		
Engine Type:	EMD-16 Cyl	*Mile/Hrs*				
Equipment Type:	GP 35	*ID #:*	4006		*Baro*	29.81
Fuel Sp. Gravity(SG	.853	*Temp:*	57			
					Time:	8:35

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
8	853.2	9.6	0.21	26	5.76	13.6	
8	858.4	9.6	0.21	26	5.74	13.6	
8	862.4	9.6	0.21	25	5.68	13.7	
8	864.8	9.6	0.21	25	5.68	13.7	
8	865.8	9.6	0.21	24	5.75	13.7	
8.000	**860.920**	**9.600**	**.210**	**25.200**	**5.722**	**13.660**	Mean
0	**5.172**	**.000**	**.000**	**.837**	**.039**	**.055**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
2.52E-05	0.0021	.057	.137	29.463	110,536	21,307

Company Name:	Wisc.-Central	*Location:*	Stevens Point		*Test Date:*	8/14/96
Test Portion:	Treated	*Stack Diam:*	8	Inches		
Engine Type:	EMD-16 Cyl	*Mile/Hrs:*				
Equipment Type	GP 35	*ID #:*	4006		*Baro:*	29.95
Fuel Sp. Gravity:	.853	*Temp:*	60			
SG Corr Factor:	1.000				*Time:*	9:45

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
8	891.4	9	0.2	45	5.36	14.5	
8	893.2	9	0.2	44	5.42	14.4	
8	890.8	9	0.19	42	5.37	14.7	
8	892	9	0.2	42	5.39	14.6	
8	897.8	9	0.2	44	5.41	14.6	
8.000	**893.040**	**9.000**	**.198**	**43.400**	**5.390**	**14.560**	Mean
0	**2.805**	**.000**	**.004**	**1.342**	**.025**	**.114**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.34E-05	0.00198	.054	.146	29.447	117,014	23,632

Performance factor adjusted for fuel density: 23,632

****% Change PF= 10.91 %**

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

Company Name:	Wisc.-Central	*Location*	Stevens Point	*Date:*	6/19/96

10.0 **<u>APPENDIX 4</u>**

CARBON MASS BALANCE FORMULAE

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 ^oF

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

EQUATIONS:

Mwt =

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

$$\text{pf1 or pf2} = \frac{3099.6 \times Mwt}{86(VFHC)+13.89(VFCO)+13.89(VFCO_2)}$$

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

$$\text{PF1 or PF2} = \frac{pf \times (Te+460)}{CFM}$$

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)

$$CFM = \frac{(d/12)^2\pi}{144}\left(1096.2\sqrt{\frac{Pv}{1.325(PB/ET+460)}}\right)$$

d =Exhaust stack diameter in inches
Pv =Velocity pressure in inches of H_2O
P_B =Barometric pressure in inches of mercury
Te =Exhaust temperature ^{O}F

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

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)

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

$$\text{Mwt2} = 28.980$$

Equation 3 (Calculated Performance Factor)

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

$$\text{pf2} = 349{,}927$$

Equation 4 (CFM Calculations)

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

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

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

$$\text{CFM} = 2320.51$$

Equation 5 (Corrected Performance Factor)

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

$$= 115{,}966$$

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:)

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

$$\% \text{ Change PF} = [(116{,}384 - 108{,}115)/108{,}115](100)$$

$$= +7.65$$

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

11.0 **APPENDIX 5**

DR. G. J. GERMANE'S RESUME'

Abbreviated Resume -- December 1994

Geoffrey J. Germane, Ph.D.
Germane Engineering
1790 North 120 East
Orem, Utah 84057

Professor and Chair, Department of Mechanical Engineering
242 CB
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.

4. Germane, G.J., and Heaton, H.S., "Dynamic Tests with Ethanol and Methanol in Hydrocarbon Fuel," Mechanical Engineering Report ER-1, Brigham Young University, Provo, UT, May, 1979.

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.

6. Germane, G.J., and Heaton, H.S., "A Dynamic Engine Test Facility with Motoring Using a Digital Computer," SAE Paper 800412, Society of Automotive Engineers International Congress and Exposition, Detroit, MI, February, 1980.

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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20. Germane, G.J., Smoot, L.D., and Cannon, J.N., "Inerting of Coal Pulverizers," Paper 83-JPGC-Fu-4, ASME Joint Power Generation Conference, Indianapolis, IN, September 27, 1983.

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22. Germane, G.J., Hess, C.C. and Wood, C.G., "Lean Combustion in Homogeneous Charge Spark Ignition Engines--A Review," SAE Paper 831694, Society of Automotive Engineers Fuels and Lubricants Meeting, San Francisco, CA, November, 1983.

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2. "Dispenser for Slender Objects, " U. S. Patent granted to Geoff J. Germane, Richard D. Ulrich and David B. Anderson, 1982.

12.0 APPENDIX 6

BAROMETRIC PRESSURE READINGS

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*  WEATHERBANK NOW PUBLISHES A QUARTERLY NEWSLETTER! Subscribe to  *
*  the RainMaker now for just $10 a year! Spring issues will be    *
*  mailed this month!  Call Customer Service for more info.        *
*                                                                  *
*  THE POLLEN INDEX MAP HAS BEEN REPLACED BY A NEW ULTRAVIOLET     *
*  INDEX MAP!  Choose Custom Industrial Graphics from the menu, &  *
*  enter code #1, product G001 to select the new map.              *
* --------------------------------------------------------------- *
*     ** ISO-GRAPHIC menu has been upgraded for version 5.0! **    *
*     See the HELP NEWS file for details on downloading upgrades.  *
*  WEATHERBANK MOVES!  See the HELP MOVE file for our new info.    *
*  CUSTOMER SERVICE: (M-F, 8:30 am - 6:00 pm. CT) . .405-359-0773  *
*  INTERNET E-Mail Address:  wxbank@thor.net                       *
*  INTERNET Home Page:       http://www.thor.net/~wxbank           *
********************************************************************
ONLINE....
+
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STATION FILE: WI   06-18-16 GMT

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Eau Claire	94	62	35	103			/0	6 BKN 10 OVC
18-04P*	Eau Claire	EAU SP 1608 5 SCT E10 OVC 21/2L-F/0608/981							
18-04P*	Eau Claire	EAU SP 1620 8 SCT E10 OVC 7/0605/981							
18-05P	Eau Claire	63	60	90	64	E 10	29.81	10	10 OVC
18-06P	Eau Claire	64	62	93	69	E 7	29.81	15	10 OVC
18-07P	Eau Claire	67	60	78	70	E 9G16	29.80	15	14 OVC
18-08P	Eau Claire	65	60	84	69	E 7G17	29.81	15	14 OVC
18-09P	Eau Claire	66	61	84	71	NE 7	29.81	15	14 OVC
18-10P	Eau Claire	66	61	84	70	E 8	29.81	15	14 OVC
18-11P	Eau Claire	66	61	84	70	NE 8	29.81	15	16 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Rhinelander	58			47	E 14G21	29.87	3R-F	6 OVC
18-05P	Rhinelander	58			47	E 14	29.88	3L-F	6 OVC
18-06P	Rhinelander	58			50	E 10	29.88	3F	4 OVC
18-07P	Rhinelander	59			52	E 10	29.88	21/2R-F	4 BKN 8 OVC
18-08P*	Rhinelander								
18-09P*	Rhinelander								
18-09P*	Rhinelander	RHI SP 2107 E7 BKN 10 OVC 5R-F 60/M/0807/987							
18-10P	Rhinelander	61			53	NE 11	29.86	6R-F	7 OVC
18-11P	Rhinelander	61			54	E 10	29.86	7	6 BKN 10 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Wausau	60	57	90	59	E 10	29.83	7R-	7 OVC
18-05P	Wausau	61	58	90	63	E 7	29.84	7	7 OVC
18-06P	Wausau	61	58	90	61	NE 9	29.84	7	7 OVC
18-07P	Wausau	61	59	93	66	E 5	29.84	7R-	7 OVC
18-07P*	Wausau	AUW SP 1920 E7 OVC 10 0703/984/RE18							
18-08P	Wausau	61	58	90	62	E 8	29.84	10	7 OVC
18-08P*	Wausau	AUW SP 2024 E8 OVC 10 0705/983							
18-09P	Wausau	62	58	87	60	E 11	29.84	10	8 OVC
18-10P	Wausau	62	58	87	65	NE 6	29.83	10	8 OVC
18-11P	Wausau	62	58	87	64	E 7	29.82	10	8 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Mosinee	57	56	96	53	E 11	29.82	10R-	7 OVC
18-05P	Mosinee	57	56	96	53	E 11	29.83	7	7 OVC

18-06P	Mosinee	58	56	93	55	NE 10	29.82	10R-	7 OVC
18-07P	Mosinee	58	56	93	52	E 15G18	29.83	10	9 OVC
18-08P	Mosinee	59	57	93	55	NE 13	29.83	10	9 OVC
18-09P	Mosinee	59	57	93	55	E 14G20	29.83	10	7 OVC
18-10P	Mosinee	59	57	93	55	NE 13	29.82	10	7 OVC
18-11P	Mosinee	59	57	93	55	E 14	29.81	10	7 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Green Bay	60	60	100	60	NE 11	29.82	11/4R-L-	3 OVC
18-05P	Green Bay	61	60	97	60	NE 13	29.81	2R-L-F	3 OVC
18-06P	Green Bay	61	60	97	59	NE 14	29.81	21/4F	3 OVC
18-07P	Green Bay	60	60	100	60	NE 11	29.82	2F	3 OVC
18-08P	Green Bay	61	60	97	61	NE 11	29.81	2F	3 OVC
18-09P	Green Bay	61	60	97	62	NE 10	29.80	21/2F	5 OVC
18-10P	Green Bay	61	60	97	62	NE 10	29.79	2L-F	5 OVC
18-11P	Green Bay	62	60	93	61	NE 13	29.79	2L-F	5 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Appleton	59	59	100	54	E 17	29.80	1/4R-F	1 X
18-05P	Appleton	60	60	100	54	NE 23	29.80	3/8R-F	1 X
18-06P	Appleton	60	60	100	56	NE 17	29.79	1/8F	1 X
18-07P	Appleton	60	60	100	56	NE 17	29.80	3/8F	1 X
18-08P	Appleton	60	59	97	55	NE 17	29.80	1/4F	1 X
18-09P	Appleton	60	59	97	55	NE 17	29.79	1/4F	1 X
18-09P*	Appleton	ATW SP 2125 W1 X 1/2L-F 0516/978							
18-10P	Appleton	60	59	97	55	NE 17	29.78	3/4L-F	2 X
18-11P	Appleton	60	60	100	57	NE 16	29.78	1L-F	2 X

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Oshkosh	62	61	97	62	E 11	29.77	1/2F 0	3 OVC
18-05P	Oshkosh	62	61	97	63	E 10	29.78	1/2F	3 OVC
18-06P	Oshkosh	62	61	97	63	E 10	29.77	3/4F	3 OVC
18-07P	Oshkosh	62	62	100	65	E 9	29.78	1/2F	3 OVC
18-08P	Oshkosh	62	62	100	62	NE 13	29.78	1R-F	1 OVC
18-09P	Oshkosh	63	62	97	66	E 9	29.77	1R-F 0	3 OVC
18-10P	Oshkosh	63	62	97	65	NE 11	29.76	3/4R-F 0	3 OVC
18-11P	Oshkosh	62	61	97	61	NE 14	29.76	1/4F 0	3 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Manitowoc	56	54	93	53	NE 9	29.78	1/2	- X 2 OVC
18-05P	Manitowoc	56	54	93	53	NE 9	29.77	1/2	2 OVC
18-06P	Manitowoc	57	55	93	56	NE 8	29.77	5	2 OVC
18-07P	Manitowoc	57	54	90	54	NE 9	29.77	5	2 OVC
18-08P	Manitowoc	56	54	93	54	NE 8	29.77	4	2 BKN 44 OVC
18-09P	Manitowoc	57	54	90	58	N 6	29.76	5	2 BKN 40 OVC
18-10P	Manitowoc	56	53	90	55	N 7	29.75	4	4 BKN 46 OVC
18-11P	Manitowoc	55	52	90	53	NE 7	29.75	1/2	4 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	La Crosse	64	61	90	68	NE 7	29.77	21/2F	5 OVC
18-05P	La Crosse	65	61	87	69	N 7	29.78	3F	7 OVC
18-06P	La Crosse	65	61	87	68	NE 9	29.78	6F	7 OVC
18-07P	La Crosse	65	61	87	69	NE 8	29.78	5F	9 OVC
18-08P	La Crosse	66	62	87	71	E 8	29.78	5F	7 OVC
18-09P	La Crosse	67	62	84	71	NE 9	29.77	6H	13 OVC

18-10P	La Crosse	67	62	84	72	NE 8		29.78	10	10 OVC
18-11P	La Crosse	66	61	84	72	NE 6		29.78	8	10 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Camp Douglas	62	60	93	64	E 9		29.77	5L-F	5 OVC
18-05P	Camp Douglas	62	60	93	64	E 9		29.78	5L-F	5 BKN 13 OVC
18-06P	Camp Douglas	63	61	93	64	NE 10		29.78	3L-F	5 BKN 11 OVC
18-07P	Camp Douglas	63	60	90	66	NE 8		29.78	7R-	5 SCT 12 OVC
18-08P	Camp Douglas	62	60	93	63	NE 10		29.78	6R-	7 SCT 12 OVC
18-09P	Camp Douglas	63	59	87	63	NE 10		29.79	7	12 OVC
18-10P*	Camp Douglas									
18-11P*	Camp Douglas									

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Madison	66	65	97	75	E 6		29.73	2F	3 OVC
18-05P	Madison	66	66	100	74	NE 8		29.72	2F	3 OVC
18-06P	Madison	66	66	100	75	NE 7		29.73	1/2F	3 OVC
18-07P	Madison	67	66	97	75	N 8		29.73	1/2F	5 OVC
18-08P	Madison	66	65	97	69	N 14		29.74	1/2F	7 OVC
18-09P	Madison	66	65	97	69	NE 13		29.73	5F	OVC
18-10P	Madison	67	65	93	72	NE 10		29.73	10+	9 OVC
18-11P	Madison	67	65	93	73	NE 9		29.72	10+	OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Janesville					S 7		29.71	7	47 BKN 100 OVC
18-05P	Janesville					SW 7		29.71	7	47 BKN 100 OVC
18-06P*	Janesville									
18-07P	Janesville					N 8		29.71	4F	12 BKN 40 OVC
18-08P	Janesville					E 11		29.71	5RF	13 BKN 40 OVC
18-09P*	Janesville									
18-09P*	Janesville	JVL SP 2124 M7 BKN 20 OVC 2RW-F 0112/971								
18-10P	Janesville					N 11		29.71	11/2RW-F	7 BKN 27 OVC
18-11P	Janesville					N 9		29.71	11/2RW-F	4 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Milwke Mitch	59	58	97	62	E 6		29.73	1/4R-F 0	1 X
18-05P	Milwke Mitch	59	59	100	64	NE 5		29.73	1/2F 0	1 OVC
18-06P	Milwke Mitch	60	59	97	63	N 7		29.72	1/4F 0	1 OVC
18-07P	Milwke Mitch	57	56	96	52	N 13		29.73	1/2R-F 0	1 OVC
18-08P	Milwke Mitch	58	56	93	57	N 8		29.73	1/2F 0	1 OVC
18-09P	Milwke Mitch	60	57	90	62	NE 7		29.73	1/2F	1 OVC
18-10P	Milwke Mitch	58	56	93	59	N 7		29.72	1/2F	3 OVC
18-11P	Milwke Mitch	56	55	96	56	N 7		29.72	1/4F	1 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Milwke Timme					E 6		29.75	1/4F	0 X
18-05P	Milwke Timme					E 9		29.75	1/4F	0 X
18-06P	Milwke Timme					E 9		29.75	1/2R-F	1 X
18-06P*	Milwke Timme	MWC SA 1745 W1 X 1/2R-F M/M/0908/975								
18-07P	Milwke Timme					NE 11		29.76	3/4R-F	- X 3 OVC
18-08P	Milwke Timme					NE 11		29.75	1F	- X 3 OVC
18-09P	Milwke Timme					NE 11		29.74	5/8F	1 X
18-10P	Milwke Timme					NE 11		29.74	3/8F	1 X
18-11P	Milwke Timme					NE 9		29.74	5/16F	0 X

19-10A	Wausau	59	58	97	63	NE 5		29.82	11/2F	4 OVC
19-11A	Wausau	60	57	90	63	NE 6		29.83	11/2F	3 OVC
19-11A*	Wausau	AUW SP 1127 E3 OVC 2F 0507/983								
19-12P	Wausau	60	57	90	62	E 7		29.84	21/2F	3 OVC
19-12P*	Wausau	AUW SP 1212 E4 OVC 3F 1305/984								
19-01P	Wausau	61	58	90	65	E 5		29.84	4F	4 BKN 8 OVC
19-02P	Wausau	62	58	87	62	NE 9		29.84	4F	4 BKN 8 OVC
19-02P*	Wausau	AUW SP 1411 E7 BKN 15 OVC 5F 0000/985								
19-03P	Wausau	63	57	81	69	E 3		29.86	6F	7 BKN 15 OVC
19-04P	Wausau	63	60	90	71	CALM		29.87	4L-F	7 OVC
19-05P	Wausau	64	60	87	71	NE 5		29.87	5F	7 BKN 15 OVC
19-05P*	Wausau	AUW SP 1718 E10 BKN 15 OVC 6F 0000/989								
19-06P	Wausau	65	60	84	73	NE 3		29.88	6F	10 BKN 15 OVC
19-07P	Wausau	67	60	78	74	NE 5		29.87	7	10 BKN 15 OVC
19-08P	Wausau	68	60	76	76	NW 3		29.86	7	10 BKN 15 OVC
19-09P	Wausau	69	61	76	76	W 5		29.86	7	12 BKN 15 OVC
19-09P*	Wausau	AUW UA/OV AUW/TM 2154/FLUNKN/TP PA31/SK OVC 040/CLR ABV								
19-10P	Wausau	68	61	78	76	CALM		29.84	7	14 OVC
19-11P	Wausau	69	62	79	78	CALM		29.85	7	14 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A	Mosinee	57	56	96	56	NE 8		29.83	2F	2- X 3 OVC
19-06A	Mosinee	57	57	100	58	NE 7		29.82	2F	2- X 3 OVC
19-07A	Mosinee	57	57	100	57	NE 8		29.81	2F	2- X 3 OVC
19-08A	Mosinee	57	57	100	61	NE 5		29.81	1/2F	2- X 3 OVC
19-09A	Mosinee	57	57	100	61	NE 5		29.81	3/4F	2- X 3 OVC
19-10A	Mosinee	57	57	100	60	NE 6		29.82	1F	2- X 3 OVC
19-11A	Mosinee	57	57	100	60	NE 6		29.82	3/4F	- X 3 OVC
19-12P	Mosinee	57	57	100	60	NE 6		29.83	1F	- X 3 OVC
19-12P*	Mosinee	CWA SP 1200 AO2A -X M3 OVC 2F 0506/983								
19-01P	Mosinee	57	57	100	60	NE 6		29.83	3F	3 OVC
19-02P	Mosinee	58	57	97	61	NE 6		29.84	4F	3 OVC
19-02P*	Mosinee	CWA SP 1404 AO2A M5 OVC 5F 0304/985								
19-03P	Mosinee	59	58	97	63	NE 5		29.85	7	5 OVC
19-04P	Mosinee	61	60	97	66	N 6		29.87	10	5 OVC
19-05P	Mosinee	62	59	90	69	N 3		29.87	10	8 OVC
19-05P*	Mosinee	CWA SP 1720 AO2A M10 OVC 10 0303/988								
19-06P	Mosinee	62	60	93	69	N 5		29.87	7	10 OVC
19-07P	Mosinee	64	61	90	68	N 7		29.86	7	10 OVC
19-08P	Mosinee	65	62	90	74	CALM		29.86	10	12 OVC
19-09P	Mosinee	65	62	90	74	CALM		29.86	10	14 OVC
19-10P	Mosinee	67	62	84	76	CALM		29.83	10	16 OVC
19-11P	Mosinee	66	62	87	75	CALM		29.84	7	16 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A	Green Bay	61	61	100	63	NE 9		29.80	2L-F	2 OVC
19-06A	Green Bay	61	60	97	65	NE 7		29.79	2L-F	2 OVC
19-07A	Green Bay	60	60	100	63	NE 8		29.79	1L-F	2 OVC
19-08A	Green Bay	60	60	100	63	NE 8		29.79	1L-F	2 OVC
19-09A	Green Bay	60	60	100	63	NE 8		29.78	11/2L-F	2 OVC
19-10A	Green Bay	60	60	100	63	NE 8		29.78	1L-F	2 OVC
19-10A*	Green Bay	GRB SP 1026 M1 OVC 1/2L-F 0407/979								
19-11A	Green Bay	60	60	100	63	N 8		29.80	1/4L-F	1 OVC
19-12P	Green Bay	60	60	100	65	NE 6		29.80	1/2L-F	2 OVC
19-01P	Green Bay	60	60	100	64	NE 7		29.81	1/2L-F	2 OVC
19-02P	Green Bay	61	60	97	64	NE 8		29.82	11/2F	3 OVC
19-03P*	Green Bay									

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19-04P Green Bay      64  62  93  70 N    6      29.83 5F           5 OVC
19-05P Green Bay      67  63  87  73 NE   8      29.83 6F           9 OVC
19-05P*Green Bay      GRB SP 1747 M10 OVC 6F 0205/984
19-06P Green Bay      67  63  87  75 NE   6      29.84 6F          10 OVC
19-06P*Green Bay      GRB SP 1747 M10 OVC 6F 0205/984
19-07P Green Bay      68  63  84  75 NE   7      29.83 6F          10 OVC
19-08P Green Bay      68  63  84  76 NE   6      29.83 7           12 OVC
19-09P Green Bay      68  64  87  76 NE   6      29.82 7           10 OVC
19-09P*Green Bay      GRB UA/OV GRB 180010/TM 2155/FLUNKN/TP UNKN/SK UNKN
                      OVC 046/CLR ABV
19-10P Green Bay      68  64  87  77 N    5      29.84 7           12 OVC
19-11P Green Bay      67  64  90  76 N    5      29.82 6F          12 OVC

DY-HR      TOWN       TMP DEW HUM FLK WIND GST   PRSSR VSBLY-WX   CLOUD COVER
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19-05A*Appleton
19-06A*Appleton
19-07A*Appleton
19-08A*Appleton
19-09A*Appleton
19-10A Appleton       58  58 100  57 N    9      29.79 3/8L-F      1   X
19-11A Appleton       58  58 100  57 N    9      29.79 1/2L-F      1   X
19-12P Appleton       58  58 100  57 NE   9      29.80 1/4F        1   X
19-01P Appleton       58  58 100  53 NE 14      29.81 3/8F        1   X
19-01P*Appleton       ATW SP 1300 W1 X 3/4F 58/58/0212/981
19-02P*Appleton
19-03P Appleton       61  60  97  63 N    9      29.82 2F          3   X
19-04P Appleton       62  60  93  64 NE   9      29.83 4F          3 OVC
19-05P Appleton       64  61  90  67 N    9      29.84 5F          5 OVC
19-06P Appleton       64  61  90  69 N    6      29.85 7           6 OVC
19-07P Appleton       65  62  90  72 N    6      29.85 7           6 OVC
19-08P Appleton       64  62  93  70 NW   6      29.84 11/2L-F     6 OVC
19-09P Appleton       66  62  87  74 NW   5      29.84 7           6 OVC
19-10P Appleton       67  63  87  75 NW   6      29.83 7           8 OVC
19-11P Appleton       67  63  87  72 N    9      29.82 7           7 OVC

DY-HR      TOWN       TMP DEW HUM FLK WIND GST   PRSSR VSBLY-WX   CLOUD COVER
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19-05A Oshkosh        62  61  97  63 NE 10      29.78 1/2R-F      3 OVC
19-06A Oshkosh        61  61 100  63 NE   9      29.77 2RF         3 OVC
19-07A Oshkosh        61  61 100  62 NE 10      29.76 1/2R-F      3 OVC
19-08A Oshkosh        61  61 100  63 NE   9      29.75 5F          3 OVC
19-09A Oshkosh        61  60  97  62 NE 10      29.75 7           3 OVC
19-10A Oshkosh        61  60  97  62 NE 10      29.77 3F          3 OVC
19-11A Oshkosh        61  60  97  62 NE 10      29.77 1/2F        3 OVC
19-12P Oshkosh        60  59  97  63 NE   7      29.79 1/4R-F 0    3 OVC
19-01P Oshkosh        60  59  97  62 N    8      29.80 3R-F   0    3 OVC
19-02P Oshkosh        61  59  93  63 NE   8      29.81 1/2R-F 0    3 OVC
19-03P Oshkosh        61  60  97  63 NE   9      29.81 3R-F   0    3 OVC
19-04P Oshkosh        63  61  93  70 NE   5      29.82 3R-F   0    5 OVC
19-05P Oshkosh        64  61  90  69 N    6      29.84 4F     0    7 OVC
19-06P Oshkosh        63  62  97  68 N    7      29.84 1/4F          OVC
19-06P*Oshkosh        OSH SP 1819 AO2A M5V OVC 2F 092/63/62/3505/984/CIG 3V9
19-07P Oshkosh        64  62  93  69 N    7      29.83 3F            OVC
19-07P*Oshkosh        OSH SP 1924 AO2A M7V OVC 2R-F 090/64/63/3604/983/CIG
                      4V10 RB21 PCPN 0001
19-07P*Oshkosh        OSH SP 1946 AO2A M7V OVC 3F 089/65/63/3504/983/CIG
                      4V10 RB21E36 PCPN 0001
19-08P Oshkosh        65  63  93  73 N    6      29.83 3F     0      OVC
19-09P Oshkosh        65  63  93  71 N    8      29.83 5F            OVC
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19-10P	Oshkosh	66	63	90	73	N 7		29.83	7	7 OVC
19-11P	Oshkosh	67	63	87	76	N 5		29.81	7 0	12 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A	Manitowoc	56	54	93	58	NE 5		29.76	2 0	- X 2 OVC
19-06A	Manitowoc	55	54	96	56	N 6		29.75	3	2 OVC
19-07A	Manitowoc	55	53	93	54	N 7		29.75	1/4	- X 2 OVC
19-08A	Manitowoc	56	54	93	57	N 6		29.75	1	- X 2 OVC
19-09A	Manitowoc	56	54	93	55	N 7		29.75	3/4	- X 2 OVC
19-10A	Manitowoc	55	53	93	57	NE 5		29.75	1/2	- X 2 OVC
19-11A	Manitowoc	56	54	93	58	N 5		29.76	1/4	- X 2 OVC
19-12P	Manitowoc	57	55	93	60	N 5		29.77	1/4	- X 2 OVC
19-01P	Manitowoc	58	56	93	59	N 7		29.78	1/4	- X 2 OVC
19-02P	Manitowoc	59	58	97	65	N 3		29.78	1/4	- X 2 OVC
19-03P	Manitowoc	60	59	97	64	N 6		29.78	3/4	- X 2 OVC
19-04P	Manitowoc	62	61	97	70	NE 3		29.79	5	2 OVC
19-05P	Manitowoc	64	62	93	70	NE 6		29.80	5	6 OVC
19-06P	Manitowoc	66	62	87	75	CALM		29.80	5	8 BKN 14 OVC
19-07P	Manitowoc	67	63	87	77	CALM		29.79	7	13 OVC
19-08P	Manitowoc	67	63	87	72	NW 9		29.79	5	11 OVC
19-09P	Manitowoc	66	62	87	71	N 8		29.79	5	9 OVC
19-10P	Manitowoc	67	62	84	74	N 6		29.79	7	11 OVC
19-11P	Manitowoc	59	55	87	61	E 6		29.79	7	13 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A	La Crosse	63	60	90	71	CALM		29.82	7	10 OVC
19-06A*	La Crosse									
19-07A	La Crosse	62	61	97	70	CALM		29.81	13/4L-F	4 X
19-08A	La Crosse	62	62	100	71	CALM		29.81	13/4L-F	4 X
19-09A	La Crosse	62	62	100	71	CALM		29.80	13/4L-F	4 X
19-10A	La Crosse	63	62	97	72	CALM		29.80	2F	5 OVC
19-11A	La Crosse	63	62	97	69	N 6		29.80	3F	5 OVC
19-12P	La Crosse	63	61	93	68	N 6		29.82	3F	6 OVC
19-01P	La Crosse	64	61	90	69	N 6		29.83	21/2F	4 OVC
19-02P	La Crosse	65	62	90	73	NE 5		29.85	21/2F	4 OVC
19-03P	La Crosse	66	62	87	75				3F	6 OVC
19-04P	La Crosse	66	62	87	73	NW 6		29.87	3F	6 OVC
19-04P*	La Crosse	LSE SP 1625 E4 OVC 4F 3405/988								
19-05P	La Crosse	67	63	87	75	N 6		29.88	4F	6 OVC
19-06P	La Crosse	68	63	84	73	NW 9		29.88	5F	6 OVC
19-07P	La Crosse	68	63	84	72	NW 11		29.88	4H	7 OVC
19-08P	La Crosse	72	64	76	82	N 7		29.85	4H	9 OVC
19-08P*	La Crosse	LSE SP 2002 E11 OVC 4H 3406/986/CIG RGD								
19-09P	La Crosse	73	65	76	84	N 7		29.84	4H	11 OVC
19-10P	La Crosse	73	64	74	83	W 6		29.85	4H	11 BKN 17 OVC
19-11P	La Crosse	72	65	79	83	N 6		29.86	5H	11 BKN 22 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A*	Camp Douglas									
19-06A*	Camp Douglas									
19-07A*	Camp Douglas									
19-08A*	Camp Douglas									
19-09A*	Camp Douglas									
19-10A*	Camp Douglas									
19-11A*	Camp Douglas									
19-12P*	Camp Douglas									
19-01P	Camp Douglas	61	60	97	67	NE 5		29.82	2F	3 OVC

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19-01P*Camp Douglas VOK SP 1324 M3 OVC 23/4F 0304/983 CIG RGD
19-02P Camp Douglas  61  60  97  67 N    5     29.84 3F          4 OVC
19-02P*Camp Douglas VOK SP 1413 M5 OVC 3F 0504/983 CIG RGD
19-03P Camp Douglas  62  60  93  70 NW   3     29.85 3F          5 OVC
19-04P Camp Douglas  63  61  93  67 NW   7     29.86 4F          6 OVC
19-05P Camp Douglas  65  62  90  72 N    6     29.87 4F          9 OVC
19-05P*Camp Douglas VOK SP COR 1737 M11V OVC 4F 3205/986 CIG 9V13
19-06P Camp Douglas  66  62  87  74 N    5     29.87 5F            OVC
19-07P Camp Douglas  67  62  84  73 W    7     29.86 6H            OVC
19-08P Camp Douglas  69  63  81  75 W    8     29.85 6H            BKN  28 OVC
19-09P Camp Douglas  70  64  81  80 NW   7     29.84 6H            BKN  25 OVC
19-10P Camp Douglas  72  65  79  83 N    2     29.83 6H         16 SCT  20 BKN
19-11P Camp Douglas  71  63  76  81 E    5     29.83 6H         19 SCT  25 BKN

DY-HR     TOWN        TMP DEW HUM FLK WIND GST  PRSSR VSBLY-WX   CLOUD COVER
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19-05A Madison       63  63 100  69 N    7     29.77 7           5 OVC
19-06A Madison       62  62 100  70 NW   5     29.76 3F          3 OVC
19-07A Madison       62  62 100  68 NW   6     29.75 1/2F          OVC
19-08A Madison       62  62 100  70 N    5     29.75 1/2F        3 OVC
19-09A Madison       61  61 100  65 NW   7     29.76 3F            OVC
19-10A Madison       61  61 100  66 NW   6     29.77 5F            OVC
19-11A Madison       61  61 100  66 NW   6     29.77 3             BKN  27 OVC
19-12P Madison       62  62 100  66 N    8     29.78 3F            OVC
19-01P Madison       63  62  97  71 NW   5     29.80 10+         5 OVC
19-02P Madison       64  62  93  70 N    6     29.81 10+         7 OVC
19-03P*Madison
19-04P Madison       64  62  93  72 NW   5     29.83 10+           OVC
19-05P Madison       66  63  90  72 NW   8     29.83 10+           BKN  21 OVC
19-06P Madison       66  63  90  73 N    7     29.84 10+           OVC
19-07P Madison       66  63  90  73 N    7     29.84 10+         9 BKN  18 OVC
19-07P*Madison      MSN SP 1941 AO2A M11 BKN 26 BKN 39 OVC 10+ 100/69/65
                    /3605/983
19-08P Madison       70  65  84  81 N    6     29.83 10+        13 BKN  30 OVC
19-08P*Madison      MSN SP 2012 AO2A M15 OVC 10+ 100/69/65/3605/983
19-09P Madison       71  66  84  83 N    7     29.83 10+        15 OVC
19-10P Madison       70  66  87  82 N    6     29.82 10+        19 OVC
19-11P*Madison

DY-HR     TOWN        TMP DEW HUM FLK WIND GST  PRSSR VSBLY-WX   CLOUD COVER
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19-05A*Janesville
19-06A*Janesville
19-07A*Janesville
19-08A*Janesville
19-09A*Janesville
19-10A*Janesville
19-11A Janesville                   NW   6     29.77 1F          7 OVC
19-11A*Janesville   JVL SA 1045 M7 OVC 1F 3305/977
19-12P Janesville                   NW   9     29.77 1F          3 OVC
19-01P Janesville                   NW   9     29.79 2F          5 OVC
19-02P Janesville                   NW   9     29.81 21/2F       7 OVC
19-03P Janesville                   W    9     29.82 4F          9 OVC
19-04P Janesville                   NW   9     29.83 4F         11 OVC
19-05P Janesville                   NW   9     29.83 5F         12 OVC
19-06P Janesville                   N   10     29.83 5F         13 OVC
19-07P*Janesville
19-08P Janesville                   NW   9     29.83 5F         13 OVC
19-09P Janesville                   NW  11     29.84 5F         15 OVC
19-10P Janesville                   N    9     29.83 5F         17 OVC
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19-11P	Janesville					NW	9	29.83	5F	16 OVC
19-11P*	Janesville	JVL SA 2259 M16 OVC 5F 3308/983								

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A	Milwke Mitch	54	54	100	58	N	3	29.76	1/4F	1 BKN 6 OVC
19-06A	Milwke Mitch	55	54	96	57	N	5	29.74	1/4F	1 OVC
19-07A	Milwke Mitch	56	55	96	61	CALM		29.74	1/4F	3 OVC
19-08A	Milwke Mitch	56	55	96	61	CALM		29.74	1/4F	3 OVC
19-09A	Milwke Mitch	58	56	93	63	CALM		29.74	1F	3 OVC
19-10A	Milwke Mitch	57	55	93	62	CALM		29.75	2F	3 OVC
19-11A	Milwke Mitch	58	56	93	63	CALM		29.76	1/2F	3 OVC
19-12P	Milwke Mitch	57	56	96	59	N	6	29.76	1/2F	3 OVC
19-01P	Milwke Mitch	58	56	93	60	NE	6	29.78	1/4F	1 OVC
19-02P	Milwke Mitch	59	57	93	65	CALM		29.79	1/2F	3 BKN 8 OVC
19-03P*	Milwke Mitch									
19-04P	Milwke Mitch	62	58	87	64	NE	7	29.80	3	8 OVC
19-05P	Milwke Mitch	61	58	90	64	NE	6	29.82	3F	8 OVC
19-06P	Milwke Mitch	61	57	87	61	NE	9	29.82	7	8 OVC
19-07P	Milwke Mitch	61	58	90	64	NE	6	29.82	4F	2 SCT 8 OVC
19-08P	Milwke Mitch	64	60	87	72	CALM		29.82	1/2F	6 OVC
19-09P	Milwke Mitch	63	60	90	67	E	7	29.81	4F	6 OVC
19-10P	Milwke Mitch	66	62	87	75	CALM		29.81	1/2F	6 OVC
19-11P	Milwke Mitch	63	61	93	70	E	5	29.81	1/2F	6 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A*	Milwke Timme									
19-06A*	Milwke Timme									
19-07A*	Milwke Timme									
19-08A*	Milwke Timme									
19-09A*	Milwke Timme									
19-10A*	Milwke Timme									
19-11A*	Milwke Timme									
19-12P	Milwke Timme					CALM		29.78	1F	- X 2 OVC
19-01P	Milwke Timme					CALM		29.79	1/2F	- X 1 OVC
19-02P	Milwke Timme					CALM		29.80	11/2F	2 OVC
19-03P	Milwke Timme	62			59	NW	6	29.81	11/2F	3 OVC
19-04P	Milwke Timme	63			63	CALM		29.81	3F	3 OVC
19-05P*	Milwke Timme									
19-06P	Milwke Timme	66			66	CALM		29.83	11/2F	6 OVC
19-07P	Milwke Timme	66			64	N	6	29.83	11/2F	6 OVC
19-08P	Milwke Timme	67			62	N	9	29.83	3F	6 BKN 9 OVC
19-09P	Milwke Timme	67			63	NE	8	29.82	3F	7 OVC
19-10P	Milwke Timme	68			65	NW	7	29.82	3F	7 OVC
19-11P	Milwke Timme	68			64	N	8	29.83	3F	9 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A	Sturgeon Bay	56	53	90	54	E	8	29.82	3/4	- X 2 OVC
19-06A	Sturgeon Bay	56	53	90	54	E	8	29.81	1/4	- X 1 OVC
19-07A	Sturgeon Bay	57	54	90	58	NE	6	29.81	3/4	- X 2 OVC
19-08A	Sturgeon Bay	57	54	90	61	NE	3	29.81	1/4	- X 1 OVC
19-09A	Sturgeon Bay	58	55	90	60	NE	6	29.80	3/4	- X 1 OVC
19-10A	Sturgeon Bay	57	54	90	58	NE	6	29.80	3/4	- X 1 OVC
19-11A	Sturgeon Bay	57	54	90	58	NE	6	29.81	1/4	- X 1 OVC
19-12P	Sturgeon Bay	57	54	90	58	N	6	29.82	1/4	- X 1 OVC
19-01P	Sturgeon Bay	57	55	93	59	NE	6	29.82	3	2 OVC
19-02P	Sturgeon Bay	58	55	90	61	NE	5	29.82	1/2	- X 1 OVC
19-03P	Sturgeon Bay	60	57	90	66	CALM		29.83	4	2 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
19-04P	Sturgeon Bay	60	57	90	61	NW 8	29.83	4	3 OVC
19-05P	Sturgeon Bay	59	56	90	60	NW 7	29.85	4	2 OVC
19-06P	Sturgeon Bay	60	57	90	62	N 7	29.85	7	4 SCT 17 OVC
19-07P	Sturgeon Bay	59	55	87	57	N 10	29.85	5	2 OVC
19-08P	Sturgeon Bay	60	56	87	60	N 8	29.84	7	4 BKN 14 OVC
19-09P	Sturgeon Bay	59	55	87	58	N 9	29.84	7	4 BKN 31 OVC
19-10P	Sturgeon Bay	57	54	90	55	N 8	29.85	5	2 OVC
19-11P	Sturgeon Bay	57	54	90	55	N 8	29.84	5	2 BKN 16 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A*	Rice Lake								
19-06A*	Rice Lake								
19-07A*	Rice Lake								
19-08A*	Rice Lake								
19-09A*	Rice Lake								
19-10A*	Rice Lake								
19-11A*	Rice Lake								
19-12P*	Rice Lake								
19-01P*	Rice Lake								
19-02P*	Rice Lake								
19-03P*	Rice Lake								
19-04P*	Rice Lake								
19-05P*	Rice Lake								
19-06P*	Rice Lake								
19-07P*	Rice Lake								
19-08P*	Rice Lake								
19-09P*	Rice Lake								
19-10P*	Rice Lake								
19-11P*	Rice Lake								

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A*	Waukesha								
19-06A*	Waukesha								
19-07A*	Waukesha								
19-08A*	Waukesha								
19-09A*	Waukesha								
19-10A*	Waukesha								
19-11A	Waukesha	61			61	CALM	29.77	3/4L-F	3 OVC
19-12P	Waukesha	61			61	CALM	29.77	3/4L-F	3 OVC
19-01P	Waukesha	62			59	N 6	29.79	1L-F	3 OVC
19-01P*	Waukesha	UES SP 1328 W3 X 1/4F 0000/979							
19-02P	Waukesha	62			62	CALM	29.80	1/2F	1 X
19-03P	Waukesha	64			64	CALM	29.81	5/8F	3 X
19-04P	Waukesha	65			65	CALM	29.82	11/2F	3 OVC
19-05P	Waukesha	65			63	NW 6	29.83	2F	4 OVC
19-06P	Waukesha	65			63	NW 6	29.83	21/2F	4 OVC
19-07P	Waukesha	66			60	NW 11	29.84	11/2F	5 OVC
19-08P	Waukesha	66			60	NW 11	29.84	21/2F	5 OVC
19-09P	Waukesha	67			61	NW 11	29.83	21/2F	5 OVC
19-10P	Waukesha	66			60	NW 11	29.83	4F	5 OVC
19-11P	Waukesha	67			63	NW 8	29.83	4F	6 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
19-05A*	Phillips								
19-06A*	Phillips								
19-07A*	Phillips								
19-08A*	Phillips								

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STATION FILE: WI     06-19-05 GMT
DY-HR     TOWN         TMP DEW HUM FLK WIND GST   PRSSR VSBLY-WX   CLOUD COVER
====== ============ === === === === ========   ===== ======== ===============
19-05A Eau Claire    64  60  87  68 E    7     29.83 15          11 SCT  14 OVC
19-05A*Eau Claire    EAU SP 0534 7 SCT M11 OVC 10 0708/983
19-06A Eau Claire    64  60  87  67 E    8     29.82 10           7 SCT  11 OVC
19-07A Eau Claire    63  60  90  71 NE   3     29.82 10           7 SCT  11 OVC
19-08A Eau Claire    63  60  90  67 E    7     29.82 10           7 SCT  12 OVC
19-08A*Eau Claire    EAU SP 0832 COR 10 SCT M12 OVC 10 0505/982
19-09A Eau Claire    63  60  90  68 NE   6     29.82 10          10 SCT  13 OVC
19-10A Eau Claire    62  60  93  69 N    5     29.81 15          10 SCT  13 OVC
19-11A Eau Claire    62  60  93  67 NE   6     29.82 15          10 SCT  12 OVC
19-11A*Eau Claire    EAU SP 1135 E13 OVC 15 0705/983
19-12P Eau Claire    63  60  90  68 E    6     29.83 15          13 OVC
19-01P Eau Claire    63  60  90  70 E    5     29.84 15          10 BKN  20 OVC
19-01P*Eau Claire    EAU SP 1315 E8 BKN 22 OVC 15/0805/984
19-01P*Eau Claire    EAU SP 1341 E10 BKN 22 OVC 15/0704/985
19-02P Eau Claire    64  60  87  69 NE   6     29.84 15          10 BKN  22 OVC
19-03P Eau Claire    66  61  84  74 CALM       29.86 15          10 OVC
19-04P Eau Claire    68  61  78  74 NW   6     29.88 15          12 BKN  20 OVC
19-05P Eau Claire    69  63  81  77 N    6     29.87 15          14 OVC
19-06P Eau Claire    70  62  76  79 N    7     29.89 15          16 OVC
19-07P Eau Claire    71  64  79  81 N    7     29.88 15          16 BKN  32 BKN
19-08P Eau Claire    73  64  74  83 N    6     29.85 15          16 BKN
19-08P*Eau Claire    EAU SP 2036 E21 BKN 15/1003/982
19-09P Eau Claire    75  64  69  85 E    5     29.81 15          21 BKN
19-10P Eau Claire    75  65  71  86 NW   6     29.84 15/         23 OVC
19-11P Eau Claire    74  64  71  84 NE   3     29.84 15          29 BKN

DY-HR     TOWN         TMP DEW HUM FLK WIND GST   PRSSR VSBLY-WX   CLOUD COVER
====== ============ === === === === ========   ===== ======== ===============
19-05A*Rhinelander
19-06A*Rhinelander
19-07A*Rhinelander
19-08A*Rhinelander
19-09A*Rhinelander
19-09A*Rhinelander   RHI SP 0945 E3 OVC 11/2F 57/M/0608/984/CIG RGD FIRST
19-10A*Rhinelander
19-11A Rhinelander   58          54 E    7    29.84 3/4F          3 OVC
19-12P Rhinelander   59          59 E    3    29.84 3F            2 BKN   6 OVC
19-01P Rhinelander   59          53 NE   9    29.85 7             3 OVC
19-02P Rhinelander   60          57 E    6    29.85 7             3 OVC
19-03P Rhinelander   60  60 100  64 NE   7    29.86 6F            3 OVC
19-04P Rhinelander   61          59 NE   5    29.88 6F            3 OVC
19-05P Rhinelander   62          62 CALM      29.89 7             5 OVC
19-06P Rhinelander   63          63 CALM      29.89 7             6 OVC
19-07P Rhinelander   67          67 N    3    29.88 6H            9 BKN  15 OVC
19-08P Rhinelander   68          68 CALM      29.88 7            15 OVC
19-09P Rhinelander   68          67 NE   5    29.87 7            15 OVC
19-10P*Rhinelander
19-11P Rhinelander   68          68 CALM      29.85 10           15 OVC

DY-HR     TOWN         TMP DEW HUM FLK WIND GST   PRSSR VSBLY-WX   CLOUD COVER
====== ============ === === === === ========   ===== ======== ===============
19-05A*Wausau
19-06A Wausau        59  58  97  62 E    6    29.83 11/4L-F       2    X
19-07A Wausau        59  58  97  62 NE   6    29.82 11/8L-F       2    X
19-08A Wausau        59  58  97  60 NE   8    29.82 13/8F         3    X
19-09A Wausau        59  58  97  62 NE   6    29.82 15/8F         2 SCT   4 OVC
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DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Sturgeon Bay	56	53	90	52	NE 10	29.85	2	- X 2 OVC
18-05P	Sturgeon Bay	55	52	90	47	NE 13	29.85	2	- X 2 OVC
18-06P	Sturgeon Bay	56	53	90	49	NE 14G21	29.85	3	3 OVC
18-07P	Sturgeon Bay	58	54	87	53	NE 11G21	29.84	5	4 OVC
18-08P	Sturgeon Bay	60	56	87	56	E 13G18	29.84	7	5 SCT 15 OVC
18-09P	Sturgeon Bay	61	57	87	57	E 15G25	29.83	7	19 BKN
18-10P	Sturgeon Bay	60	55	84	58	E 10G20	29.83	7	19 OVC
18-11P	Sturgeon Bay	59	55	87	53	E 15G22	29.82	7	6 SCT 19 OVC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	*Rice Lake								
18-05P	*Rice Lake								
18-06P	*Rice Lake								
18-07P	*Rice Lake								
18-08P	*Rice Lake								
18-09P	*Rice Lake								
18-10P	*Rice Lake								
18-11P	*Rice Lake								

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	Waukesha	63			57	NE 9	29.74	1/16F	0 X
18-05P	Waukesha	63			57	NE 9	29.74	1/8L-F	0 X
18-06P	Waukesha	63			58	E 8	29.74	3/4L-F	2 OVC
18-07P	Waukesha	63			57	NE 9	29.73	3/4R-F	3 OVC
18-08P	*Waukesha								
18-09P	Waukesha	62			56	NE 9	29.74	6F	5 OVC
18-10P	Waukesha	62			56	NE 9	29.73	21/2F	4 OVC
18-11P	Waukesha	60			57	NE 6	29.73	1/8F	0 X

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
18-04P	*Phillips								
18-05P	*Phillips								
18-06P	*Phillips								
18-07P	*Phillips								
18-08P	*Phillips								
18-09P	*Phillips								
18-10P	*Phillips								
18-11P	*Phillips								

UG-1996 MOUNTAIN STANDARD TIME

D-HH-MM	TOWN	TMP	DPT	HUM	FLK	WIND	GST	BRMTR	VIS	WEATHER	MAX	MIN
.4-00-45	Milwke Timmer											
.4-01-45	Milwke Timmer											
.4-02-45	Milwke Timmer											
.4-03-45	Milwke Timmer											
.4-04-45	Milwke Timmer											
.4-05-45	Milwke Timmer											
.4-07-00	Milwke Timmer					SW 7		29.96	52	prtly cldy		
.4-07-50	Milwke Timmer					SW 14		29.96	52	prtly cldy		
.4-08-50	Milwke Timmer					W 14		29.96	52	prtly cldy		
l4-09-50	Milwke Timmer					W 18		29.95	52	mstly cldy		
l4-10-50	Milwke Timmer					SW 11		29.94	68	prtly cldy		
l4-11-50	Milwke Timmer					W 14		29.94	68	fair		
14-12-50	Milwke Timmer					SW 14		29.93	100	prtly cldy		
14-13-50	Milwke Timmer					W 16		29.92	100	mstly cldy		
14-14-50	Milwke Timmer					W 14		29.91	100	mstly cldy		
14-15-50	Milwke Timmer					NW 17		29.91	100	mstly cldy		
14-16-45	Milwke Timmer											
14-17-50	Milwke Timmer					NW 16		29.91	180	prtly cldy		
14-18-50	Milwke Timmer					NW 11		29.92	180	prtly cldy		
14-19-50	Milwke Timmer					W 11		29.92	180	mstly cldy		
14-20-50	Milwke Timmer					NW 8		29.93	180	mstly cldy		
14-21-45	Milwke Timmer											
14-22-45	Milwke Timmer											
14-23-45	Milwke Timmer											

13.0 **APPENDIX 7**

CARBON BALANCE TEST DATA

Carbon Mass Balance Field Data Form RAIL ROAD TEST

Company: Wis-Central Location: Steven's Point Test Date: 8-14-96

Test Portion: Baseline: [redacted] Treated: X Exhaust Stack Diameter: 12" Inches

Engine Make/Model: EMB-12 Cylinder Miles/Hours: ________ I.D.#: 1550

Type of Equipment: SW-1550

Fuel Specfic Gravity: .853 @: ________ (°F)

Barometric Pressure: ____________ inches of Mercury Start Time: 8:15

DATE: ____________

Oil Pressure	Pyro Temp	RPM OR RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x ENG RACK SETTING	AMPS	VOL
33 PSI	146°	330.4 RPM 404.4 IDLE 2	251.8	1.6	01	13	1.43	19.0	1.60	344	232
		2	254.2	1.6	01	15	1.45	19.1			
		2	253.0	1.6	01	13	1.40	19.3			
		2	253.4	1.5	01	13	1.38	19.3			
R-2	R-2	2	256.0	1.5	01	13	1.41	19.3		R-2	R-
48 PSI	147°	578 RPM 4	480.6	4.4	01	13	3.40	17.3	1.30	760	51
		4	483.4	4.4	01	13	3.38	17.2			
		4	487.0	4.4	01	17	3.34	17.3			
		4	485.0	4.3	01	17	3.31	17.3			
R-4	R-4	4	486.6	4.3	01	17	3.33	17.3		R-4	R-

Shutter's Open
More Air

O'PACITY @ REGULAR RACK = 3
RACK-2 = 4
RACK-4 = 6½

Names of Customer Personnel Participating in Test:

____________ ____________

Signature of Technicians:

____________ ____________

Test Portion: Baseline: X Treated:_____ Exhaust Stack Diameter: 12 inches

Engine Make/Model: EMB-12 CYLINDER Miles/Hours:______ I.D.#: 1550
Type of Equipment: SW-1550

Fuel Specfic Gravity: __________ @:______ (°F)

Barometric Pressure: __________ inches of Mercury Start Time:________

DATE: __________

OIL PRESSURE	PYR TEMP	RPM RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x	AMPS	VOL
50 PSI	157°	727.6 / 6	674.8	6.7	03	19	4.44	16.0	1.09	992	66
		6	678.0	6.7	02	17	4.41	16.0			
		6	682.6	6.7	02	19	4.40	16.0			
		6	685.8	6.7	03	19	4.53	15.9			
R-6	R-6	6	685.4	6.7	02	19	4.51	16.0		R-6	R-
		8									
		8									
		8									
		8									
R-8	R-8	8								R-8	R-

SHUTTER'S OPEN
MORE AIR

O'PACITY @ REGULAR RACK =
RACK 6 = 8½
RACK 8 =

Names of Customer Personnel Participating in Test:

________________ ________________

Signature of Technicians:

________________ ________________

Carbon Mass Balance Field Data Form

Company: Wisc Central Location: STEVEN'S POINT Test Date: 6-19-96

Test Portion: Baseline: X Treated: ______ Exhaust Stack Diameter: 12" Inches

Engine Make/Model: EMD-12 Cyl Miles/Hours: ______ I.D.#: 1550

Type of Equipment: ~~[illegible]~~ SW 1500

Fuel Specfic Gravity: ~~.835~~ 853 @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: 8:20 PM

Oil Pressure	Pyro Temp	RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x ENG-RACK SETTING	Amps	Volts
25 PSI	0 1 5 3	2	328 RPM REG IDLE 402 RPM 267.4	R-2 1.8	.01	17	1.51	18.7	1.60	320	240
		2	268.6	1.8	.01	17	1.51	18.8			
		2	268.8	1.6	.01	15	1.46	18.8			
		2	269.0	1.6	.01	15	1.46	18.8			
R-2	R-2	2	269.6	1.6	.01	15	1.50	18.8		R-2	R-2
40 PSI	0 1 4 7	580 4	[illegible] RPM 477.6	4.6	.02	18	3.48	16.4	1.30	725	575
		4	481.2	4.6	.02	18	3.48	16.4			
		4	486.6	4.6	.02	18	3.51	16.3			
		4	489.2	4.6	.02	18	3.50	16.3			
R-4	R-4	4	491.8	4.6	.02	18	3.49	16.3		R-4	R-4

O'PACITY REG RACK = 4

Shutters Open MORE AIR

Names of Customer Personnel Participating in Test: RK 2 = 6 1/2

RK 4 = 8

Mark Kusch Jerry Riske

Craig Flanders & Kris La Baron w/ UHI

Signature of Technicians:

Paul Kramer & Dick Rennal w/ FPC Great Lakes

Carbon Mass Balance Field Data Form

Company: Wisc Central Location: Steven's Point Test Date: 6-19-96

Test Portion: Baseline: X Treated: ______ Exhaust Stack Diameter: 12" Inches

Engine Make/Model: EMB-12 cyl Miles/Hours: ______ I.D.#: 1550

Type of Equipment: ~~GP9~~ SW1500

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: 8:20PM

Oil Pressure	Pyro Temp	RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO ~~Eng Rack~~ Setting	Amps	Volts
60 PSI	158	6	730RPM 671.2	7.0	.03	23	4.66	14.7	1.08	980	680
		6	673	7.0	.03	23	4.64	14.7			
		6	681.0	7.0	.02	22	4.67	14.8			
		6	685.4	7.0	.02	23	4.63	14.7			
R-6	R-6	6	687.4	7.0	.02	23	4.71	14.7		R-6	R-6
50 PSI	167	8	905RPM 864.4	9.0	.19	37	5.65	13.2	.87	1150	830
		8	867.4	9.0	.18	37	5.64	13.1			
		8	872.4	9.0	.19	37	5.64	13.2			
		8									
R-8	R-8	8								R-8	R-8

Oil Pacity Test Reg Rack =
Rack 6 = 9
Rack 8 = 9+

Names of Customer Personnel Participating in Test:

Mark Kusch Jerry Rishe

Craig Flindas & Kim La Baron w/ UHF

Signature of Technicians:

Paul Kramer & Dick Remmel w/ FRC Short Line

Carbon Mass Balance Field Data Form RAIL ROAD TEST

Company: Wisconsin-Central Location: STEVEN'S POINT Test Date: 8-14-96

Test Portion: Baseline:______ Treated:______ Exhaust Stack Diameter: 8" Inches

Engine Make/Model: EMD-16 CYLINDER Miles/Hours:______ I.D.#: 4009

Type of Equipment: N/A

Fuel Specfic Gravity: .854 @:______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: 8:15AM

DATE: ______

OIL PRESSURE	PYRO TEMP	RPM or RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x ENG-RACK SETTING	AMPS	VOL
22 PSI	1[illegible]	IDLE 375.3 2	289.0	1.65	01	15	1.61	19.0	1.72 IDLE 1.59 [illegible]	675	228
34 PSI	146°	2	283.6	1.7	01	15	1.51	19.0			
		2	283.6	1.7	01	15	1.50	19.0			
		2	283.6	1.7	01	15	1.49	19.0			
R-2	R-2	2	283.4	1.7	01	15	1.51	19.0		R-2	R-2
43 PSI	173°	559 RPM 4	508.0	3.8	02	27	3.85	16.3	1.28	1300	450
		4	510.0	3.7	02	27	3.85	16.3			
		4	510.0	3.7	02	24	3.84	16.5			
		4	511.2	3.7	02	26	3.82	16.4			
R-4	R-4	4	510.8	3.7	02	26	3.82	16.4		R-4	R-4

Shutter's Open

None Air

O'PACITY @ REGULAR RACK = 3 — IDLE 6

RACK-2 = [illegible]

RACK-4 = 6

Names of Customer Personnel Participating in Test:

____________ ____________

Signature of Technicians:

____________ ____________

Carbon Mass Balance Field Data Form RAILROAD TEST

Company: Wis-Central Location: Steven's Point Test Date: 8-14-96

Test Portion: Baseline: ______ Treated: X Exhaust Stack Diameter: 8 Inches

Engine Make/Model: EMB-16 Cylinder Miles/Hours: ______ I.D.#: 4009

Type of Equipment: n/a

Fuel Specfic Gravity: ______ @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: ______

DATE: ______

OIL PRESSUR	PYRO TEMP	RPM RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x RACK SETTING	AMPS	VOLTS
3 51	168°	719.2 RPM 6	687.4	6.8	09	32	4.89	15.2	1.06	1675	585
		6	689.2	6.8	09	32	4.89	15.1			
		6	690.8	6.8	09	31	4.92	15.2			
		6	691.4	6.8	09	31	4.92	15.2			
-6	R-6	6	692.0	6.8	09	31	4.88	1.52		R-6	R-6
7 1	176°	893.8 RPM 8	868.0	9.0	25	44	5.79	14.1	.84	1950	690
		8	871.0	9.0	25	44	5.81	13.9			
		8	875.2	9.0	26	41	5.75	13.8			
		8	877.4	9.0	25	39	5.72	14.1			
-8	R-8	8	882.0	9.0	27	37	5.65	14.2		R-8	R-8

HUTTER'S OPEN
1ORE AIR

O'PACITY @ REGULAR RACK =
RACK 6 = 7
RACK 8 = 9
5 Pull's For Reading

Names of Customer Personnel Participating in Test:

______ ______

Signature of Technicians:

______ ______

Carbon Mass Balance Field Data Form

Company: Wis-Central Location: Steven's Point Test Date: 6-19-96
Test Portion: Baseline: X Treated: ______ Exhaust Stack Diameter: 8" Inches

Engine Make/Model: EMB-16 CYL Miles/Hours: ______ I.D.#: 4009
Type of Equipment: N/A

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______________ inches of Mercury Start Time: 11:22AM

Oil Pressure	Pyro Temp	RPM ~~AND~~ RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	~~NO_x~~ ENG RACK SET	Amps	Volts
34 PSI	158°	310 RPM IDCL 2	276.2	1.6	.01	14	1.83	18.5	1.54	700	240
		325 RPM #2 2	276.4	1.6	.01	14	1.83	18.5		R-2	
		2	276.8	1.6	.01	14	1.83	18.6			R-2
R-2	R-2	2	277	1.6	.01	14	1.83	18.6			
		2	277.4	1.6	.01	14	1.83	18.5			
48 PSI	160°	4	481.4	4.0	.02	18	3.84	16.2	1.28	1325	460
		4	487.4	4.0	.02	17	3.80	16.2		R4	R-4
		4	493.2	4.0	.02	17	3.84	16.3			
		4	492.8	4.0	.01	17	3.83	16.3			
R-4	R-4	4	495	4.0	.02	17	3.81	16.3			

Middle & Rear fans on

O-PACITY BASELINE Reg Idle = 4½
RACK 2 = 7
RACK 4 = 8

Names of Customer Personnel Participating in Test:

Mark Kusch Jerry Raske

Signature of Technicians:

Craig Flinders Kim La Baron UHI Corp
Paul Kramm Dick Reveral FPC Great Lakes

Carbon Mass Balance Field Data Form

Company: Wis- Central Location: Steven's Points Test Date: 6-19-96
Test Portion: Baseline: X Treated: ______ Exhaust Stack Diameter: 8" Inches

Engine Make/Model: EMB - 16 Cyl Miles/Hours: ______ I.D.#: 4009
Type of Equipment: ______

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: ______

Oil Pressure	Pyro Temp	RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO ~~ENG RACK~~	Amps RACK SET	Volts
49 PSI	1607	6	725 RPM 668.4	7.2	.10	20	4.92	14.8	1.06	1700	600
		6	672.8	7.2	.10	21	4.91	14.8			
		6	677.6	7.2	.09	20	4.89	15.0		R-6	R-6
		6	678.8	7.2	.09	21	4.89	15.0			
R-6	R-6	6	679.2	7.2	.09	21	4.92	14.9			
60 PSI	1666	8	899 RPM 848.8	9.4	.29	23	5.98	13.2	.84	2000	700
		8	852.6	9.4	.28	23	5.93	13.3			
		8	853.2	9.2	.28	23	601	13.4		R-8	R-8
R-8	R-8	8	860.2	9.2	.28	22	600	13.4			
		8	857	9.4	.29	22	592	13.5			

O'PACITY RACK 6 = 8
RACK 8 = 8½

Names of Customer Personnel Participating in Test:

MARK Kusch JERRY RISKE

Craig Flintess — Kim La Baron UHI CORP

Signature of Technicians:

Paul Rasmus Dick Revenal FRC Grant Lohr

Carbon Mass Balance Field Data Form RAIL ROAD TEST

Company: WIS-CENTRAL Location: STEVEN'S POINT Test Date: 8-14-96
Test Portion: Baseline: [redacted] Treated: X Exhaust Stack Diameter: 8" Inches

Engine Make/Model: EMB-16 Cylinder Miles/Hours: ______ I.D.#: 4006
Type of Equipment: ______

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: 9:45 AM
DATE: ______

OIL PRESSURE	PYRO TEMP	RPM OR RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x ENG-RACK SETTING	AMPS	VOL
40		314.7 RPM = IDLE 2	271	1.6	.02	18	1.52	18.9	1.52	580	280
	173°	2	270.4	1.6	.02	18	1.52	19.0			
		381.5 2	273.4	1.6	.01	17	1.46	19.0			
		2	274.0	1.6	.01	17	1.52	19.0			
R-2	R-2	2	276.2	1.6	.02	17	1.46	19.0		R-2	R-2
49	187	574.7 4	513.6	4.0	.01	24	3.39 [redacted]	16.7	1.26	1100	510
		4	518.4	4.0	.01	24	3.39 [redacted]	16.7			
		4	517.4	4.0	.01	24	3.39 [redacted]	16.7			
		4	517.8	3.8	.01	25	3.37	16.6			
R-4	R-4	4	518.0	3.8	.01	25	3.36	16.6		R-4	R-4

Shutter's Open
More Air

O'PACITY @ REGULAR RACK = 3 LOW IDLE
RACK-2 = 4
RACK-4 = 7

Names of Customer Personnel Participating in Test:

______ ______

Signature of Technicians:

______ ______

Carbon Mass Balance Field Data Form [illegible]

Company: Wis-Central Location: Steven's Point Test Date: 8-14-96

Test Portion: Baseline: [redacted] Treated: X Exhaust Stack Diameter: 6 Inches

Engine Make/Model: EMB-16 Cylinder Miles/Hours: ______ I.D.#: 4006

Type of Equipment: ______

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: 10:00

DATE: ______

Oil Pressure	Pyro Temp	RPM [redacted]	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x	AMPS 1500	VOL 670
[illegible]1 PSI	175°	736.2 RPM 6	691.6	6.8	03	28	4.57	15.8	1.04		
		6	690.6	6.8	03	28	4.58	15.7			
		6	690.8	6.8	03	28	4.56	15.6			
		6	691.6	6.8	03	29	4.61 ~~4.70~~	15.5			
R-6	R-6	6	693	6.8	03	28	460	15.5		R-6	R-6
73 PSI	182°	909 RPM 8	891.4	9.0	20	45	5.36	14.5	.80	1760	800
		8	893.2	9.0	20	44	5.42	14.4			
		8	890.8	90	19	42	5.37	14.7			
		8	892.0	90	20	42	5.39	14.6			
R-8	R-8	8	892.8	90	20	44	5.41	14.6		R-8	R-8

SHUTTER'S OPEN
MORE AIR

O'PACITY @ REGULAR RACK =
RACK 6 = 7½
RACK 8 = 8½

Names of Customer Personnel Participating in Test:

______ ______

Signature of Technicians:

______ ______

Carbon Mass Balance Field Data Form

Company: Wisc - Central Location: Steven's Point Test Date: 6-19-96

Test Portion: Baseline: X Treated: ______ Exhaust Stack Diameter: 8 Inches

Engine Make/Model: EMB - 16 Cyl Miles/Hours: ______ I.D.#: 4006

Type of Equipment: N/A

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: 8:35 AM

Oil Press.	H_2O Temp	RPM AND RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	~~NOx~~ Rack	Amps	Volt
20 PSI	181°	LOW = 242RPM REG = 312RPM 2	262.6	1.8	.02	17	1.51	18.9		650	240
		2	263.4	1.9	.02	17	1.59	18.9			
REG 30 PSI	REG	385RPM 2	264.8	1.9	.02	17	1.51	18.9			
	181°	2	264.8	1.8	.02	17	1.51	18.9	ENGINE RACK SETTING		
32 PSI	176°	2	266.8	1.8	.02	17	1.47	19.0	2 1.54	1300	4..
4 50 PSI	4 17°	572RPM 4	484	4.2	.01	19	3.44	16.7	4 1.26		
		4	484.2	4.2	.01	19	3.43	16.7			
		4	483.2	4.2	.01	19	3.38	16.8			
		4	483.2	4.2	.01	18	3.37	16.8			
		4	482.8	4.2	.01	18	3.35	16.8			

Note! Exhaust Probe is centered @ 4"

RACK SET AT IDEAL

Baseline = 4 & 6 (low)

Rack 2 = 5

Rack - 4 = 8 1/2

Names of Customer Personnel Participating in Test:

Mark Kusch   Terry Ruske

Notch 2 = Center small fan is on

" 4 = Rear fan is on

Signature of Technicians:

Paul Kraemer   Dick Revenal   FPC Great Lakes

Carbon Mass Balance Field Data Form

Company: Wisc - Central Location: Steven's Point Test Date: 6-19-96

Test Portion: Baseline: X Treated: ______ Exhaust Stack Diameter: ___Inches

Engine Make/Model: EMB-16 CYL Miles/Hours: ______ I.D.#: 4006

Type of Equipment: N/A GP-40

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______________ inches of Mercury Start Time: 8:35AM

Oil Pressure	Pyro Temp	RPM	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x ~~Rack Smoke~~	Amps	Volts
56 PSI	1890	6	733 PRM 653.6	7.2	.03	25	4.56	15.3	ENG-ST 1.04	1675	600
		6	655.6	7.2	.03	24	4.56	15.3			
		6	657.6	7.2	.03	24	456	1.5.2			
		6	657.2	7.2	.03	23	4.56	15.2			
		6	658	7.2	.03	23	4.57	15.3			
66 PSI	8 1885	8	910 RPM 853.2	9.6	.21	26	5.76	13.6	.83	1950	700
		8	858.4	9.6	.21	26	5.74	13.6			
		8	862.4	9.6	.21	25	5.68	13.7			
		8	864.8	9.6	.21	25	5.68	13.7			
		8	865.8	9.6	.21	24	5.75	13.7			

O'PACITY — Rack 6 = 8
Rack 8 = 9+

Names of Customer Personnel Participating in Test:

Rack 4 6 8 Middle And Rear Fan On"

Mark Kusch Terry Rishe

significant accumulation at Rack 8

~~@8 large piece of carbon~~ last 6"

Some ~~[illegible]~~ accumulation at Rack 6

Signature of Technicians:

Paul Kramer Dick Revend. FPC Great Lakes

Carbon Mass Balance Field Data Form *Rail Road Test*

Company: *Wis-Central* Location: *Steven's Point* Test Date: *8-14-96*

Test Portion: Baseline: [redacted] Treated: *X* Exhaust Stack Diameter: *12"* Inches

Engine Make/Model: *EMB-12 Cylinder* Miles/Hours: ______ I.D.#: *1554*

Type of Equipment: ____________________

Fuel Specfic Gravity: *.853* @: ______ (°F)

Barometric Pressure: ____________ inches of Mercury Start Time: *2:30 P.M.*

DATE: ____________

Oil Pressure	*Pyro Temp*	RPM OR RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x *Eng-Rack Setting*	*AMPS*	*VoL*
42 PSI	*150°*	*335 RPM* *413.7* *R2* *2*	*IDLE* *238.0*	*1.7*	*01*	*15*	*1.44*	*19.0*	*1.61*	*336*	*231*
		2	*235.8*	*1.7*	*01*	*15*	*1.40*	*19.0*			
		2	*228.0*	*1.7*	*01*	*15*	*1.38*	*19.1*			
		2	*227.2*	*1.7*	*01*	*15*	*1.40*	*19.0*			
R-2	*R-2*	*2*	*225.6*	*1.6*	*01*	*15*	*1.42*	*19.0*		*R-2*	*R-2*
46 PSI	*153°*	*583 RPM* *4*	*482.2*	*5.0*	*01*	*22*	*3.52*	*16.6*	*1.25*	*792*	*54*
		4	*497.2*	*5.0*	*01*	*22*	*3.57*	*16.5*			
		4	*499.6*	*5.0*	*01*	*22*	*3.68*	*16.2*			
		4	*502.8*	*5.0*	*01*	*22*	*3.57*	*16.5*			
R-4	*R-4*	*4*	*506.8*	*5.0*	*01*	*22*	*3.56*	*16.4*		*R-4*	*R-4*

Shutters Open
More Air

O'Pacity @ Regular Rack = 3 Idle
Rack-2 = 4
Rack-4 = 7

Names of Customer Personnel Participating in Test:

______________________ ______________________

Signature of Technicians:

______________________ ______________________

Carbon Mass Balance Field Data For...

Company: Wis. Central Location: STEVEN'S POINT Test Date: ________
Test Portion: Baseline: ____ Treated: X Exhaust Stack Diameter: 12" Inches

Engine Make/Model: EMB-12 CYLINDER Miles/Hours: ______ I.D.#: 1554
Type of Equipment: n/a

Fuel Specfic Gravity: .853 @: ________ (°F)

Barometric Pressure: ____________ inches of Mercury Start Time: 2:30 PM

DATE: ____________

Oil Pressure	Pyr Temp	RPM / RACK	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	NO_x RACK SETTING	AMPS 976	VOL 706
59 PSI	152°	742.1 RPM 6	620.4	7.2	03	28	4.84	14.8	1.04	976	706
		6	622.0	7.2	03	28	4.86	14.7			
		6	612.8	7.2	03	28	4.88	15.0			
		6	618.8	7.2	03	28	4.88	15.0			
R-6	R-6	6	619.6	7.2	03	28	4.87	15.1		R-6	R-6
		8	837.9		19	38	5.55	14.0			
		8	Had To Stop - Couldn't Hold								
		8									
		8									
R-8	R-8	8								R-8	R-8

SHUTTER'S OPEN
MORE AIR

O'PACITY @ REGULAR RACK =
RACK 6 = 8
RACK 8 =

Names of Customer Personnel Participating in Test:

____________________ ____________________

Signature of Technicians:

____________________ ____________________

Carbon Mass Balance Field Data Form

Company: Wisc - Central Location: Steven's Point Test Date: 6-18-96
Test Portion: Baseline: X Treated: ______ Exhaust Stack Diameter: 12" Inches

Engine Make/Model: EMB-12 Cyl Miles/Hours: ______ I.D.#: 1554
Type of Equipment: N/A

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: 8:30PM

Oil Pressure	Pyro Temp	RPM Rack	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	~~NO_x~~ Smoke	Amps	Volts
50 PSI	150°	402RPM 2	247.6	1.8	.01	14	1.51	19.0		325	240
		2	247.8	1.8	.01	14	1.50	19.0			
		2	248.6	1.8	.01	14	1.50	19.0			
		2	249.6	1.8	.01	14	1.49	19.0		325	24
		2	250.0	1.8	.01	14	1.46	19.0			
50 PSI	155°	575RPM 4	476.8	5.0	.01	17	3.86	16.3		775	54
		4	487.6	5.0	.01	17	3.87	16.2			
		4	499	5.0	.01	18	3.83	16.2			
		4	504.4	5.0	.01	18	3.88	16.1			
50 PSI	155°	4	506.2	5.0	.01	18	3.83	16.2		775	54

Baseline Opacity =
Rack 2 = 7½
Rack 4 = 8

Names of Customer Personnel Participating in Test:

Mark Kusch

Craig Flinders & Kevin La Baron w/ UHI Corp

Signature of Technicians:

Paul Kramer Dick Reveral w/ FPC Great Lakes

Carbon Mass Balance Field Data Form

Company: Wisc Central Location: Steven's Point Test Date: 6-19-96
Test Portion: Baseline: X Treated: ____ Exhaust Stack Diameter: ___Inches

Engine Make/Model: EMB-12 CYL Miles/Hours: ______ I.D.#: 1554
Type of Equipment: N/A

Fuel Specfic Gravity: .853 @: ______ (°F)

Barometric Pressure: ______ inches of Mercury Start Time: ______

Oil Pressure	Pyro Temp	RPM Rack	Exhaust Temp °F	P Inches of H_2O	% CO	HC ppm	% CO_2	% O_2	~~NO_x~~ Smoke	Amps	Volts
50 PSI	155°	715 RPM								1000	715
		~~6~~	~~522~~	~~7.5~~	~~.02~~	~~21~~	~~4.41~~	~~14.7~~			
		6	649.8	7.5	.03	19	5.32	14.4			
		6	654.8	7.5	.03	19	5.24	14.3			
		6	655.6	7.5	.03	19	5.15	14.3			
		6	659.2	7.5	.03	19	5.16	14.4			
		6	642	7.5	.03	19	5.12	14.4			
		6	640.1	7.5	.03	19	5.10	14.4			

Mark Kusch OPACITY RACK 6 = 9

Names of Customer Personnel Participating in Test:

significant buildup at Rack 6 - Hot Carbon
massive buildup at Rack 8 - Hot Carbon

Craig Flinders & Kim La Baron W/ UHI Corp

Signature of Technicians:

Paul Kramer Dick Reneal w/FPC Grat Ltd

Table 1. Comparison of Fuel Consumption/Mass Flow Rates (PFs)

	Unit No.	Notch	Baseline PF	Treated PF	% Chg
	1554	2	62,089	67,222	8.27
	1554	4	17,014	18,325	7.71
	1554	6	11,264	11,963	6.21
Mean					**7.40**
	1550	2	65,302	70,732	8.32
	1550	4	19,387	20,846	7.53
	1550	6	13,000	13,929	7.15
Mean					**7.67**
	4009	2	123,591	144,902	17.24*
	4009	4	42,927	44,838	4.45
	4009	6	26,993	28,031	3.84
	4009	8	20,491	21,888	6.82
Mean					**5.04**
	4006	2	138,537	149,787	8.12
	4006	4	47,005	49,764	5.87
	4006	6	29,093	30,317	4.21
	4006	8	21,307	23,632	10.91+
Mean					**6.07**

Note 1: An increase in PF equates to a reduction in fuel consumption since the PF is a measure of the length of time needed to consume a unit volume of fuel. Therefore, the higher the PF, the longer the engine ran on the same quantity of fuel.

Note 2: Units 4006 and 4009 missed several fuel treatments during the engine preconditioning period. This may account for the lower fuel economy improvements when compared to the SW1500s (Units 1550 and 1554), which we fully treated during the same period.

* Statistical anomaly

+ Probable erroneous pressure reading

Table 2. Comparison of Smokespot Numbers (Smoke Density)

	Unit No.	Notch	Baseline No.	FPC No.	% Chg
	1554	idle	5.0	3.0	-40
	1554	2	7.5	4.0	-47
	1554	4	8.0	7.0	-12
	1554	6	9.0 (full scale)	8.0	-11
Mean			**7.4**	**5.5**	**-26**
	1550	idle	4.0	3.0	-25
	1550	2	6.5	4.0	-38
	1550	4	8.0	6.5	-19
	1550	6	9.0 (full scale)	8.5	- 6
Mean			**6.9**	**5.5**	**-20**
	4009	idle	4.5	3.0	-33
	4009	2	7.0	6.0	-14
	4009	4	8.0	6.0	-25
	4009	6	8.0	7.0	-12
	4009	8	8.5	9.0	6
Mean			**7.2**	**6.2**	**-16**
	4006	idle	6.0	3.0	-50
	4006	2	5.0	4.0	-20
	4006	4	8.5	7.0	-18
	4006	6	8.0	7.5	- 6
	4006	8	9.0+ (off scale)	8.5	- 6
Mean			**7.3**	**6.0**	**-19**

Note: During baseline testing at Notch 8, the Bacharach Smokemeter plugged off after three pulls on Units 1550, 1554, and 4006. When testing with FPC treated fuel, the smokemeter did not plug off. Therefore, the percentage change in smoke density at these notch settings may be greater than actually measured.

Wisconsin Central Railroad Test

Fuel Consumption Comparison