FEASIBILITY OF FPC-1® FUEL TREATMENT IN MEDIUM-SPEED LOCOMOTIVE ENGINES

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March 1995

Report No. LOCO 100R

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Abstract

This report investigates the effect of FPC-1, a combustion catalyst, upon the combustion process, particularly as it applies to medium-speed, compression-ignition engines used for locomotive power. Results of tests by Southwest Research Institute (SwRI) a recognized, independent laboratory, using the Association of American Railroads, Recommended Practice 503 (RP-503) are reviewed. Also, data from tests by the Western Australia Institute of Technology and several genset operations. Finally, a recent test by Willamette and Pacific Railroad (W&P) for the effect of FPC-1 on engine performance and emissions in a fleet of GP39-2 locomotives operating in the field are presented herein. The W&P test is the first field study comparing engine performance and emissions from several identical engines with and without FPC-1 treated fuel at multiple engine speeds (rpm) while loaded. These data confirm the addition of FPC-1 to diesel fuel used to power locomotive engines creates significant gains in fuel economy, and reductions in regulated emissions, in particular, smoke.

Further, the field data from the W&P test confirm statements made by combustion experts that the improvement in fuel economy observed in the RP-503 at SwRI will translate to improvements three times greater under field conditions.

The effect of the FPC-1 catalyst upon engine performance at maximum horsepower output (best power timing, load and rpm), under steady-state conditions represents the minimum obtainable from fuel treatment with the catalyst. Engine test data at variable engine speed, injection timing, and load more like that of engines operating in the field confirm the catalyst will have a greater effect (increased power output and improved fuel economy) under field operating conditions where losses are created by transient engine operation. Based upon these data, the economic feasibility of FPC-1 catalyst use in medium-speed, heavy duty diesel engines operated in typical field operations is determined.

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 and 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 baseline fuel treated with the combustion catalyst under these engine conditions. [Ref 1.]

Combustion experts concluded that the 1.74% improvement in bsfc (improved fuel economy) would translate to improvements of two to three times that in field engines. [Ref 8.]

The results of a Varimax engine test conducted at the Western Australia Institute of Technology (WAIT) at varying engine speeds, loads, and injection timing agreed with expert opinion and revealed FPC-1 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 reproduce engine operation under field conditions than does steady-engine testing under optimum engine operating conditions. [Ref 2.]

Data from over a dozen specific fuel consumption trials conducted under controlled conditions in the field at diesel power generating stations agree with the WAIT study. Diesel generators, although typically not subjected to as severe of transient engine 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, W.A.I.T., and stationary genset tests have verified the addition of FPC-1 to diesel fuel creates significant fuel savings in high horsepower, medium-speed diesel engines. Most recently, a test by Willamette and Pacific Railroad (W&P) undertook to determine the effect of FPC-1 upon fuel economy and emissions in a fleet of six identical GP39-2 locomotives. The results agree with those obtained in previous field tests, and the SwRI study, and prove expert opinion about FPC-1.

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 afterburning 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-1 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 and distributed by UHI Corporation 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 effected. If combustion is more complete, more energy is liberated while the flame front traverses through the fuel-air mixture. Controlled engine tests with FPC-1 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-1 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-1 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-1 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-1 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 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-1 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 BTDC
EXHAUST VALVE	OPENS 7.6 degrees BTDC
	CLOSES 21.6 degrees BTDC
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.

3.2.1 Test Method

The commencement of a new test, with the engine in a cold state, involved a set procedure. This procedure was strictly adhered to.

From initial start up the engine was run at part throttle for five minutes and then slowly brought up to full throttle in thirty seconds. This insured a gradual engine warm up. The warm up period was continued until the engine temperature reached 65 degrees C.

With the baseline tests, testing commenced once this temperature was reached and remained stable. Testing of the diesel treated with FPC-1 commenced after a engine preconditioning period. The preconditioning or delay period before actual gains in horsepower and fuel economy are witnessed had been observed in previous test programs with the catalyst, and in prior studies at WAIT.

Possible reasons for the existence of this preconditioning period are given in section 5.0. [Ref 2.]

Once testing commenced, the following readings were recorded during all tests:

(1) Brake torque

(2) The time required for the engine to consume the fuel contained in a 48 ml pipette.

(3) Exhaust temperature

(4) Ambient temperature

Five readings of brake torque and the elapse time for the consumption of 48 ml of diesel fuel were recorded at the various speeds specified in section 3.0. All readings were subsequently averaged and a mean value was recorded.

A description of the Varimax variable compression test and research rig is found in Appendix 2. [Ref 2.]

3.2.2 Discussion of WAIT Test Results

An interesting anomaly was noted at the start of the tests involving the introduction of the combustion catalyst into diesel fuel. The anticipated gains in power output and fuel economy did not occur until after a period of engine running. This anomaly, which had occurred in previous test programs, is often called the engine preconditioning period. Its cause is not fully understood, however a possible explanation will be outlined here.

The preconditioning period may be related to the time required for the combustion catalyst to react with, and slowly remove carbon deposits present on the combustion chamber surfaces. The lack of immediate power output and fuel economy improvement is probably due to the reaction between the active ingredient and the carbon deposits proceeding instead of the intended reaction between the active ingredient and the diesel fuel. It appears the catalyst may have a greater affinity for pure carbon particles than it does for hydrocarbon molecules and radicals.

Once most of the carbon deposits are removed from the engine's combustion chamber surfaces, the catalyst is free to react with the hydrocarbon molecules and radicals in its normal and intended manner. Gains in power output and fuel economy follow accordingly.

Throughout the Varimax engine test program, engine speed, throttle setting, injection timing, and catalyst concentration in the fuel were all varied to examine the effects of the combustion catalyst on the combustion process. Since the probable mode of action was to increase flame speed, confirmation of this was required in all tests. [Ref 2.]

Under all engine conditions that tend to slow flame speed, the FPC-1 catalyst showed greater effect than when the Varimax engine was tested at optimum injection timing, engine speed, throttle and load. Further, as the concentration of the catalyst was increased in the diesel fuel, greater improvement was observed. All of these facts support the theory that the FPC-1 catalyst effects flame speed, and that the catalyst will have a more profound impact upon power output and fuel economy in engines operated in the field where transient phenomenon create slower flame speeds and greater combustion time losses.

Additionally, the observed engine preconditioning period or reaction with existing combustion chamber deposits would be expected to add to the effectiveness of the catalyst under actual field operation since carbon residue tends to reduce the efficiency of an engine over time. Deposit removal from piston crowns, injectors, and ring zone areas, would restore the engine to like-new operating efficiencies.

It stands to reason then, the combined effect of FPC-1 removing engine deposits and the speeding of flame propagation when engine operating conditions are more transient, such as in commercial and industrial engines, would cause greater improvements in power output and fuel economy (bsfc).

3.2.3 Conclusions for the WAIT Study

The Varimax engine test program has shown quite convincingly the benefits of FPC-1 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-1 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-1 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 effects flame speed. [Ref 3.]

For the purposes of this paper, although still much like laboratory engine, 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 and the power output are measured. Once a reliable database has been accumulated, the fuel for the gensets is treated with FPC-1 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-1.

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 WILLAMETTE AND PACIFIC MULTIPLE ENGINE FIELD TEST

Willamette and Pacific (W&P) Railroad is a short line operating some 22 locomotives in West-Central Oregon. The fleet is comprised primarily of GP 39-2 locomotives powered by 12 cylinder, 645 Series EMD engines. The 39-2s have self-loading capability, and therefore, are ideal test engines. The W&P determined to evaluate the effect of FPC-1 upon fuel economy and smoke emissions by testing a fleet of six identical 39-2s. The fleet was divided into two groups, with three locomotives making up the control group (untreated) and three locomotives making up the FPC-1 treated group.

Both the control and treated fleet were first tested at multiple throttle settings (idle, 2, 4, 6, and 8) while loaded to 80% with baseline or untreated fuel. The treated portion of the fleet was then run on fuel with FPC-1 for approximately one month. At the end of the one month breakin period, all six locomotives were retested at identical load, and throttle setting.

3.4.1 Test Methodology

The test methodology for determining fuel consumption was the "carbon mass balance" (CMB). The CMB method measures the carbon containing products of the combustion process (CO2, CO, HC) found in the exhaust, rather than directly measuring fuel flow into the engine. The CMB also makes possible the determination of FPC-1'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]

All fuel consumption and smoke density data were recorded by a technical representative for the W&P evalution. 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), and intake air pressure (barometric) and fuel density, yielding a engine performance factor (PF) or carbon mass flow rate corrected for total exhaust mass flow and fuel energy content.

The PFs are shown on the bottom of the computer printouts found in Appendix 3. A positive change in PF equates to a reduction in fuel consumption. The CMB calculations and legend are found on Figure 1 under Appendix 4. A sample calculation is found on Figure 2, also under Appendix 4.

These calculations were provided for UHI by Dr. Geoffrey J. Germane, PhD. Mechanical Engineering, and Department Chair at Brigham Young University, as the technical approach for the CMB. Dr. Germane's resume is included in Appendix 5.

3.4.2 Correction for Fuel Density

Dr. Germane's formula assumes a fuel density of 0.82 (specific gravity of diesel). UHI engineers measure actual fuel specific gravity by taking samples from the rolling tank on each 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 shown on the treated fuel database 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 taken from the National Weather Service for the Corvallis/Albany area. The weather data are found under Appendix 6. The corrected barometric pressure is shown on the treated fuel 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 not consumed during the final phase or tail of combustion when combustion temperatures are significantly lower, and most of the oxygen in the combustion chamber has been expended. The FPC-1 catalyst improves the oxidation of these fuel droplets, extracting more useful energy and reducing smoke emissions.

Smoke from the engines tested during the baseline and treated fuel tests was collected using the Bacharach Smokespot Method. The Bacharach method draws a specific volume of exhaust gas through a standard 5 micron filter medium. The particulate in the exhaust gas sample collects on the surface of the filter medium. The surface is darkened by the particulate according to the density of the particulate in the exhaust sample. The greater the particulate density, the darker the color. The Bacharach smoke scale ranges from 0 to 9, with 0 being a white, particulate free filter, and 9 being a 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-1 treated fuel. A comparison of the baseline and treated Smoke Numbers (shown on Table 1, Appendix 7) indicate the use of FPC-1 created a reduction in smoke density of 13% to 22%.

3.4.5 Discussion of Fuel Consumption Changes

The fuel consumption data from tests at idle are not considered in this report due to the large variation in results obtained. The variations are likely a result of the difficulty in measuring the differences between very low concentrations of CO_2 and very low exhaust pressure velocities.

When the remaining throttle settings (2-8) are averaged and compared, the control group of three GP39-2s experienced a slight increase in fuel consumption (0.31%) between the two test runs. The grouping of the data points and the small average change in fuel consumption indicate the baseline was reproduced (see Table 2, Appendix 8).

When the same four throttle settings are considered, the treated group of three GP39-2s experienced a significant reduction in fuel consumption after FPC-1 fuel treatment (3.96%). The difference between the control group and the treated group averaged 4.27% The treated group results are found on Table 3, Appendix 8.

An interesting pattern of fuel consumption change was demonstrated during the test program. The effect of FPC-1 was most profound at throttle settings 2 and 8 (average 4.93% including difference between control and treated results), and least profound at throttle settings 4 and 6 (3.44%, same parameters). This would indicate that either the EMD engines powering the GP39s and/or the turbochargers for the same, are more efficient through the mid-throttle settings than the terminal settings.

This is significant since locomotives typically operate the majority of the time at throttle setting 8 (when pulling a load over the track) or at idle. The greatest volume of fuel, however, is consumed at throttle setting 8, as indicated by the exhaust gas readings (CO_2, velocity pressure, and temperature). This is consistent with information provided to the writer of this report (by Southwest Research Institute and a major railroad) that 60% or more of the fuel used by a locomotive is consumed while operating at throttle notch 8. Therefore, the fuel savings with FPC-1 treatment under actual operating conditions would be greater than 4.27% observed in this test, and could be as much as 4.5% to 5.0%.

Additionally, although more representative of the effect of FPC-1 on engine efficiency, smoke and fuel consumption in field engines than previous laboratory or stationary generator set tests, the W&P engines were still tested under steady-state conditions. Therefore, since the body of data verifies FPC-1 reduces combustion time losses, even greater fuel savings are achievable with actual field use.

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-1 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 and SwRI findings. The addition of FPC-1 to standard diesel fuel improved fuel economy approximately 3.7% in these studies. Smoke density was reduced an average of 23%.

(5) Actual field trials in a fleet of six GP39-2 locomotives agree with the above findings and conclusions, locomotive engines operating under field conditions do experience greater efficiency gains and fuel consumption reductions with FPC-1 fuel treatment than engines tested in the laboratory. The W&P trial showed minimum fuel savings with FPC-1 treatment of 4.27% under steady-state engine conditions. The reduction in fuel consumption at throttle notch 8, where the greatest volume of fuel is consumed approached 5%. Smoke density was reduced approximately 15%.

(6) These data agree with the expert opinion of Dr. Geoffrey J. Germane, Ph D., Mechanical Engineering and Chairman of the Department of Mechanical Engineering, Brigham Young University, given 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-1's benefits, also agree. [Ref 7.]

(7) The body of data and expert opinions used to compile this report agree, efficiency gains and fuel consumption reductions should be even greater during actual field operation of locomotive engines, since field operation leads to engine conditions that create greater combustion

time losses than the steady-state engine conditions observed during the RP-503, The W.A.I.T., the numerous genset tests, and the W&P tests summarized in this report.

5.0 RECOMMENDATIONS

Given the considerable independent laboratory and field data collected verifying the potential for fuel savings by treating diesel fuel with FPC-1, a large fuel consumer can realize a significant net fuel cost savings with FPC-1 fuel treatment. The data document actual fuel savings after FPC-1 fuel treatment under transient engine operating conditions will be two to three times that of the RP-503 results. Combustion experts agree with the comparison between the results of the RP-503 and results seen in engine operated in the field.

A railroad operator using FPC-1 can expect to experience fuel savings of at least 4.5%, with savings of 5.0% to 5.5% more probable. Exact fuel cost savings will depend upon the cost and volume of fuel used by the railroad. Therefore, UHI recommends the W&P commence fuel treatment with FPC-1 as soon as possible, and begin now to recover the losses being sustained from consuming untreated fuel.

UHI also recommends that, upon system wide fuel treatment, a program be initiated to determine the impact of FPC-1 upon long term engine maintenance and engine life. UHI suggests analysis of oil to determine the impact of FPC-1 upon oil viscosity and wear metals. Oil analysis and engine examination have proven the use of FPC-1 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-1 fuel treatment.

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7.0 APPENDIX 1

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**

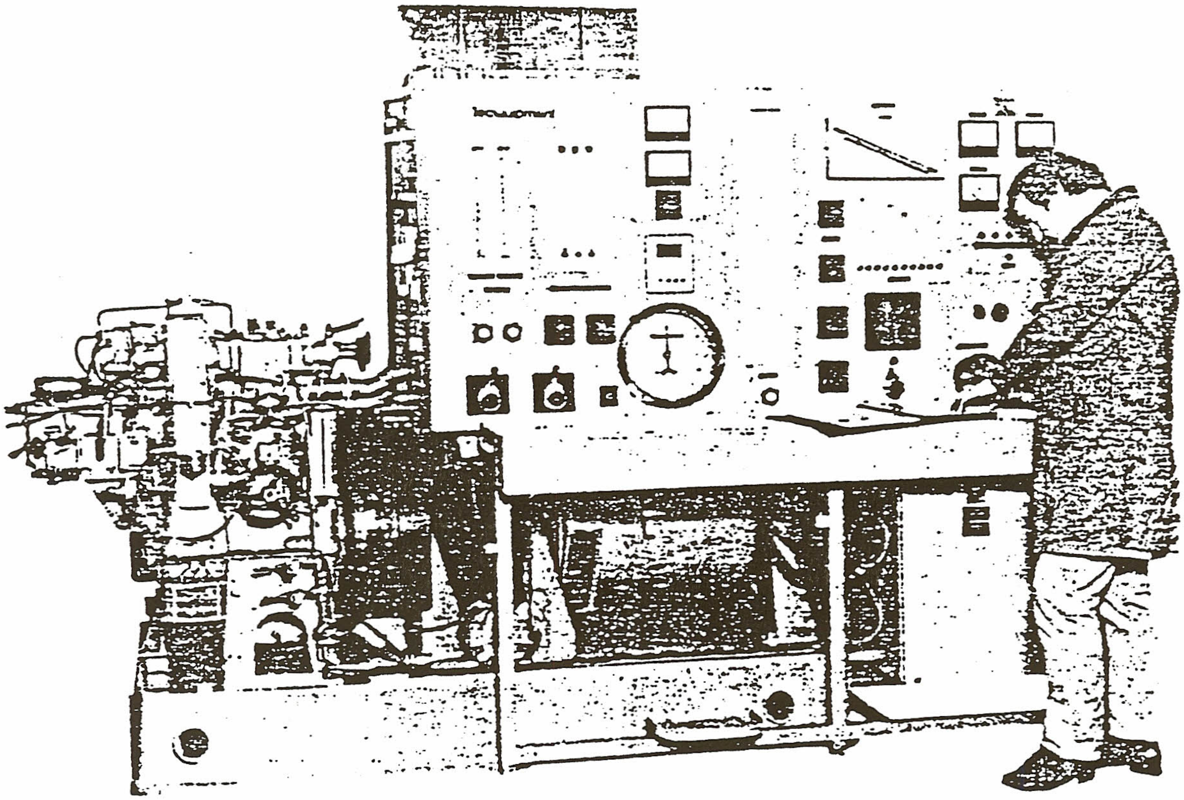
Comparison of Test Data From The W.A.I.T. Study

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

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

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 Variomax 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.

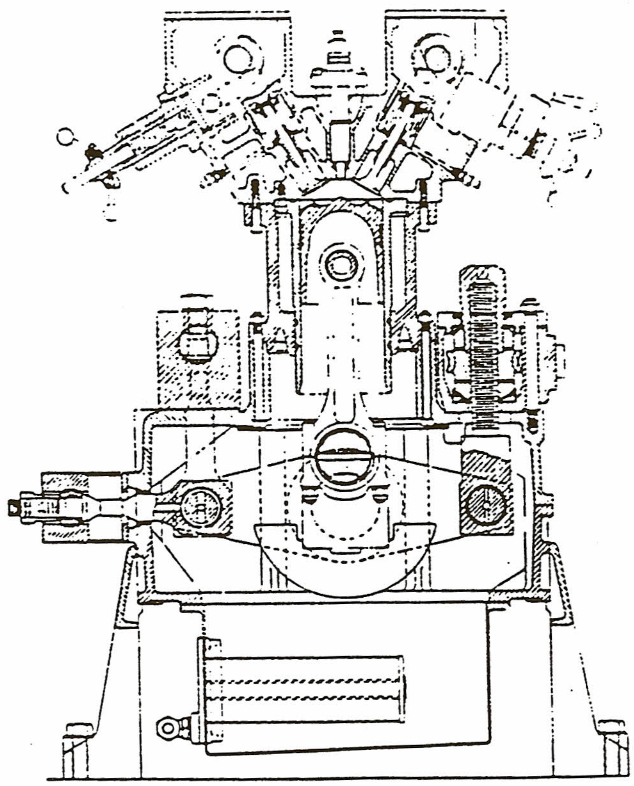
A motor driven pump circulates cooling water through the cylinder head and the cylinder liner jacket, as two separate systems. The flow through each system can be controlled independently and measured.

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

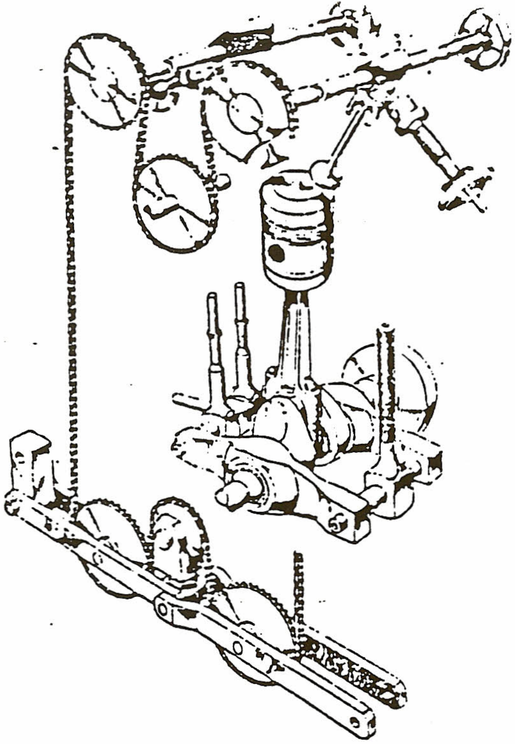
Electrical loading unit

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.

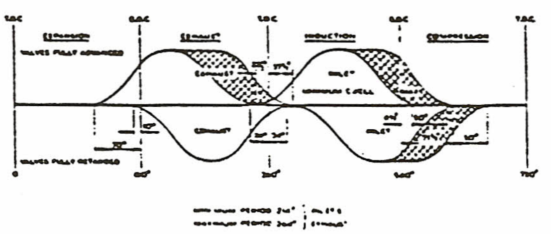
A separate circuit enables the engine to be motored for both starting and determination of friction horse power.

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.



CAMSHAFT AND DRIVE



VALVE TIMING DIAGRAM

NOMINAL VALUES ONLY

Engine services

A framework over the dynamometer incorporates the following engine services:

(a) A large capacity air intake box with a pulsation damper and an air flow measuring orifice.

(b) A cooling water mixing tank. A supply of cold water is required together with an arrangement for disposal of the overflow to drain.

(c) Four fuel tanks (2 diesel, 2 petrol).

A panel in front of the services and loading frames carries the following instruments and controls:

A three bulb pipette for fuel consumption measurements and two direct reading rotameters for continuously monitoring diesel fuel and petrol flow.

Twin flowmeters for measuring cooling water flow through the engine jacket and the cylinder head respectively. Valves for controlling the cooling water in each of these two circuits.

Master thermoelectric temperature indicator and selector switch for all water temperatures, oil temperature and air intake temperature

A separate thermoelectric indicator for exhaust temperature

Inclined-scale manometer for air orifice pressure drop

Exhaust gas sampling point

Engine rev/min Indicator

Fuel Selector taps

Throttle controls – Petrol and Diesel

Load control switches

Full/half speed load switch

Torque indicating unit

Ignition switch

Dynamometer field regulator

Decompressor lever

Lubricating oil pressure gauge

Emergency STOP button

Motor/Generator change-over switch

Starting/motoring rheostat

Dynamometer armature voltmeter

Dynamometer armature ammeter-Motoring

Dynamometer armature – Generating

Dynamometer field voltmeter

HRC Fuses to protect both Motoring and Generating circuits. Starters for oil and water pumps

Warning panel

Additional instrumentation includes a compression ratio indicator mounted on the engine.

A hand-held stroboscope is also provided to indicate both ignition and valve timing, from degree markings on the flywheel and shutters actuated by the valve tappets

The engine may be converted from diesel to petrol and vice versa in only a few minutes, without removing the cylinder head.

Electronic instrumentation

The following transducers are fitted to or incorporated in the engine:

Cylinder pressure (piezo-electric type)

Diesel fuel line pressure (resistance type)

Diesel needle lift (differential transformer)

Vertical and horizontal forces in members supporting the crankshaft (strain gauges)

Flywheel cyclic irregularity (inductive pick-up)

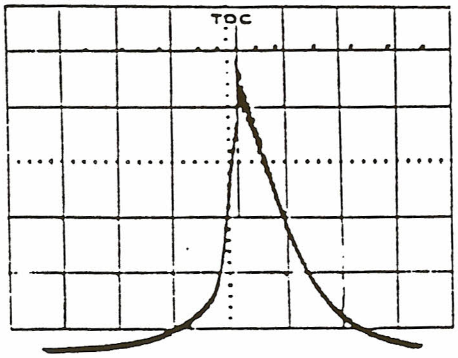
Crank angle timing (inductive pick-up)

These transducers are connected to a multi-point socket from which a cable leads to a separate free standing Electronic Control Panel TD35a Mk II.

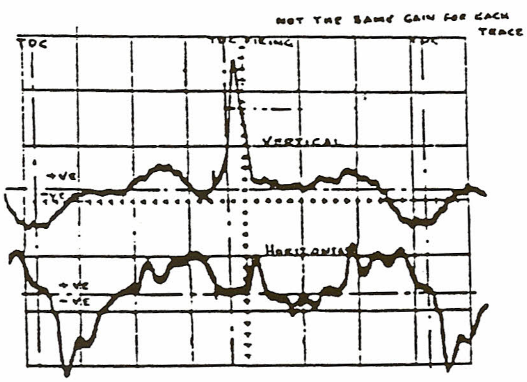
CYLINDER PRESSURE TRACES

1550 rev/min. Full throttle. 10.5:1 Compression ratio. Petrol 98 octane. 20° BTDC static ignition. 10.7 BHP 87.5 BMEP

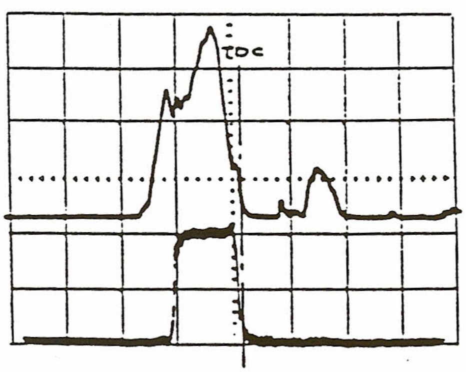
Heavy detonation



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.

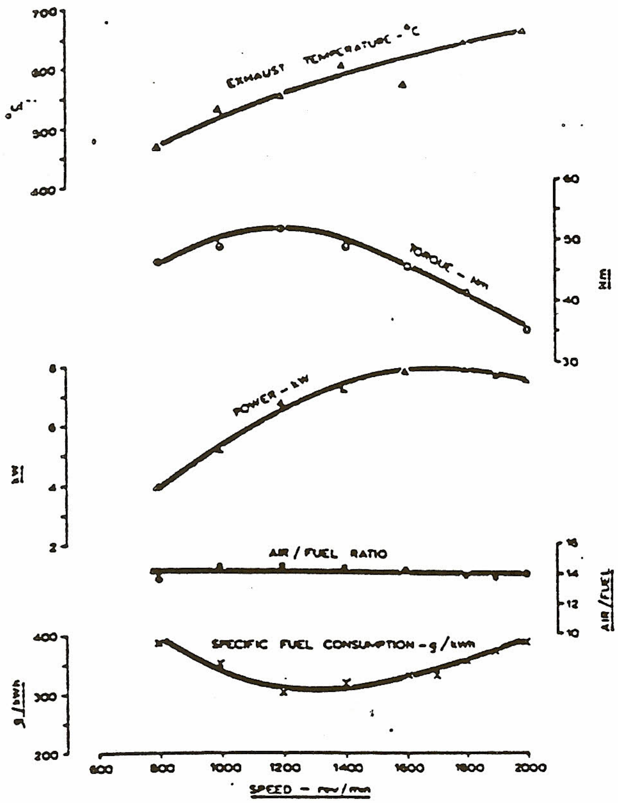
As a spark ignition engine:

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.

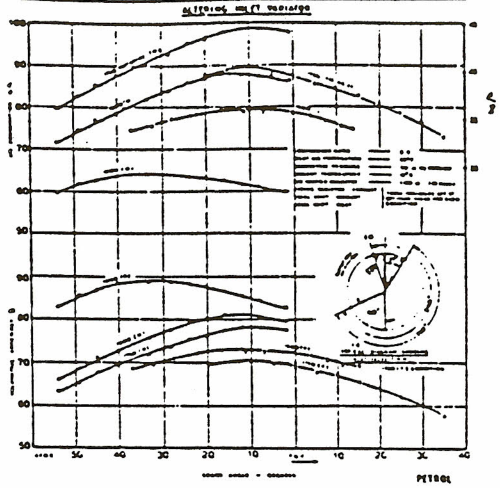
As a compression ignition engine:

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.

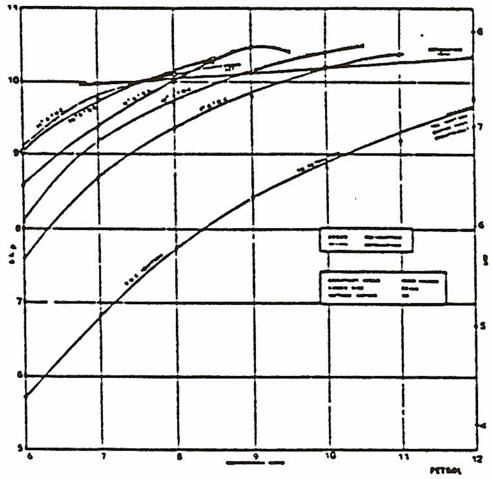
GENERAL PETROL PERFORMANCE TEST
FULL THROTTLE



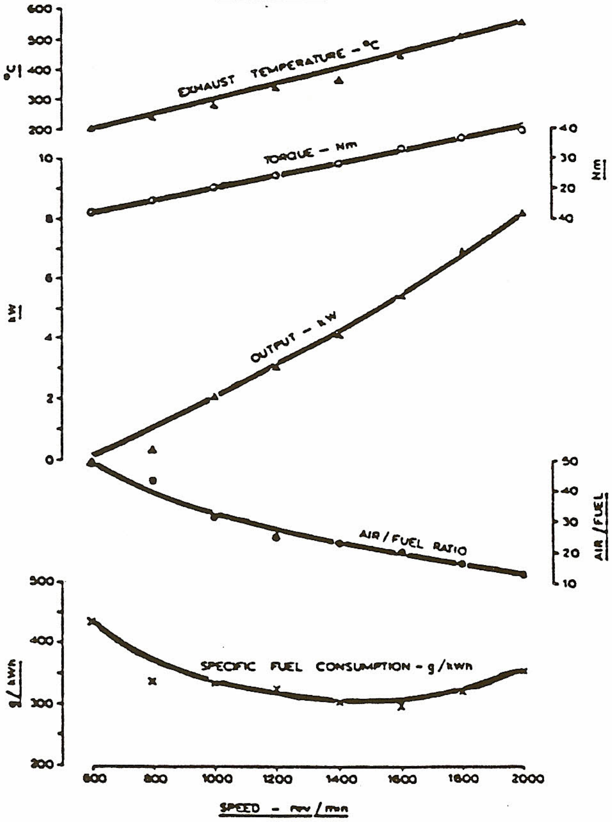
INLET VALVE OPENING V AIR CONSUMPTION & VOLUMETRIC EFFICIENCY



POWER V COMPRESSION RATIO



GENERAL DIESEL PERFORMANCE TEST
VARYING RACK



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) 8.43m^3(300ft^3): 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 APPENDIX 3

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2311	*Baro*	30.13
Fuel Sp. Gravity(SG	.855	*Temp:*	74		
				Time:	945

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	179.6	0.15	0.01	4	0.62	19.9	
Idle	179.6	0.15	0.01	4	0.62	19.9	
Idle	179.8	0.15	0.01	4	0.61	19.9	
Idle	179.8	0.15	0.01	4	0.61	20	
Idle	179.6	0.15	0.01	4	0.62	20	
Idle	179.8	0.15	0.01	4	0.62	20	
Idle	180	0.15	0.01	4	0.62	20	
Idle	179.8	0.15	0.01	4	0.62	20	
#DIV/0!	**179.750**	**.150**	**.010**	**4.000**	**.618**	**19.963**	Mean
#DIV/0!	**.141**	**.000**	**.000**	**.000**	**.005**	**.052**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.00E-06	0.0001	.006	.200	28.898	1,023,482	122,695

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2311	*Baro:*	29.64
Fuel Sp. Gravity:	.856	*Temp:*	66		
SG Corr Factor:	.999			*Time:*	930

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	176	0.2	0.01	4	0.5	19.8	
Idle	176	0.2	0.01	4	0.5	19.7	
Idle	175.8	0.2	0.01	4	0.5	19.7	
Idle	175.8	0.2	0.01	4	0.51	19.6	
Idle	176.6	0.2	0.01	4	0.5	19.7	
Idle	176.2	0.2	0.01	4	0.5	19.7	
Idle	176.2	0.2	0.01	4	0.5	19.8	
Idle	176.2	0.2	0.01	4	0.5	19.8	
#DIV/0!	**176.100**	**.200**	**.010**	**4.000**	**.501**	**19.725**	Mean
#DIV/0!	**.262**	**.000**	**.000**	**.000**	**.004**	**.071**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.00E-06	0.0001	.005	.197	28.869	1,253,824	128,740

Performance factor adjusted for fuel density: 128,589

****% Change PF= 4.80 %**

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

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2311	*Baro*	30.13
Fuel Sp. Gravity(SG	.855	*Temp:*			
				Time:	945

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	304.2	1.1	0.01	4	2.08	17.8	
Notch #2	307.2	1.1	0.01	4	2.07	17.8	
Notch #2	306.2	1.1	0.01	4	2.08	17.7	
Notch #2	305.6	1.15	0.01	4	2.07	17.7	
Notch #2	320.2	1.15	0.01	4	2.07	17.8	
Notch #2	320.8	1.15	0.01	4	2.07	17.8	
Notch #2	321.2	1.15	0.01	4	2.07	17.8	
Notch #2	321.6	1.15	0.01	4	2.07	17.8	
#DIV/0!	**313.375**	**1.131**	**.010**	**4.000**	**2.073**	**17.775**	Mean
#DIV/0!	**8.149**	**.026**	**.000**	**.000**	**.005**	**.046**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.00E-06	0.0001	.021	.178	29.043	310,830	14,919

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2311	*Baro:*	29.64
Fuel Sp. Gravity:	.856	*Temp:*	66		
SG Corr Factor:	.999			*Time:*	930

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	315.6	1.2	0	4	1.97	18.1	
Notch #2	317.6	1.2	0	4	1.97	18.1	
Notch #2	319.2	1.2	0.01	6	1.96	18.1	
Notch #2	320.4	1.2	0.01	6	1.98	18.1	
Notch #2	321.2	1.2	0.01	6	1.98	18.1	
Notch #2	322	1.2	0.01	6	1.98	18.1	
Notch #2	322.8	1.2	0.01	6	1.98	18.1	
Notch #2	323.8	1.2	0.01	6	1.98	18.1	
#DIV/0!	**320.325**	**1.200**	**.008**	**5.500**	**1.975**	**18.100**	Mean
#DIV/0!	**2.746**	**.000**	**.005**	**.926**	**.008**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
5.50E-06	0.000075	.020	.181	29.040	326,302	15,149

Performance factor adjusted for fuel density: 15,132

****% Change PF= 1.43 %**

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

Company Name:	Willamette & Pacific	Location:	Albany, OR		Date:	2/7/95
Test Portion:	Baseline	Stack Diam.	24	Inches		
Engine Type:	645E	Mile/Hrs				
Equipment Type:	Locomotive	ID #:	2311		Baro	30.13
Fuel Sp. Gravity(SG	.855	Temp:				
					Time:	945

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4		2	0.01	4	3.83	15.3	
Notch #4		2	0.01	4	3.83	15.3	
Notch #4	508	2	0.01	4	3.85	15.2	
Notch #4	506	2	0.01	4	3.85	15.3	
Notch #4	515	2	0.01	4	3.84	15.2	
Notch #4	518	2	0.01	4	3.85	15.2	
Notch #4	525	2	0.01	4	3.83	15.2	
Notch #4	521	2	0.01	4	3.83	15.2	
Notch #4	527	2	0.01	4	3.83	15.3	
Notch #4	526	2	0.01	4	3.83	15.3	
#DIV/0!	**518.250**	**2.000**	**.010**	**4.000**	**3.837**	**15.250**	Mean
#DIV/0!	**8.067**	**.000**	**.000**	**.000**	**.009**	**.053**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.00E-06	0.0001	.038	.153	29.224	169,408	6,878

Company Name:	Willamette & Pacific	Location:	Albany, OR		Test Date:	3/8/95
Test Portion:	Treated	Stack Diam:	24	Inches		
Engine Type:	645E	Mile/Hrs:				
Equipment Type	Locomotive	ID #:	2311		Baro:	29.64
Fuel Sp. Gravity:	.856	Temp:	66			
SG Corr Factor:	.999				Time:	930

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	523.8	2.1	0.01	4	3.89	15.7	
Notch #4	524.8	2.1	0.01	4	3.88	15.6	
Notch #4	525	2	0.01	4	3.88	15.6	
Notch #4	525.6	2	0.01	4	3.87	15.6	
Notch #4	526	2	0.01	4	3.87	15.6	
Notch #4	527	2	0.01	4	3.76	15.8	
Notch #4	527.6	2	0.01	4	3.87	15.7	
Notch #4	528	2	0.01	4	3.86	15.7	
#DIV/0!	**525.975**	**2.025**	**.010**	**4.000**	**3.860**	**15.663**	Mean
#DIV/0!	**1.464**	**.046**	**.000**	**.000**	**.041**	**.074**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.00E-06	0.0001	.039	.157	29.244	168,518	6,770

Performance factor adjusted for fuel density: 6,762

****% Change PF= -1.68 %**

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

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2311	*Baro*	30.13
Fuel Sp. Gravity(SG	.855	*Temp:*			
				Time:	945

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	674	3	0.06	9	5.24	13.1	
Notch #6	691	3	0.07	9	5.25	13.2	
Notch #6	694	2.95	0.06	9	5.25	13.2	
Notch #6	695	2.95	0.06	9	5.25	13.2	
Notch #6	696	2.95	0.06	9	5.25	13.2	
Notch #6	694	2.95	0.06	9	5.25	13.2	
Notch #6	696	2.95	0.06	9	5.25	13.2	
Notch #6	699	2.95	0.06	9	5.25	13.2	
#DIV/0!	**692.375**	**2.963**	**.061**	**9.000**	**5.249**	**13.188**	Mean
#DIV/0!	**7.763**	**.023**	**.004**	**.000**	**.004**	**.035**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
9.00E-06	0.0006125	.052	.132	29.368	123,285	4,463

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2311	*Baro:*	29.64
Fuel Sp. Gravity:	.856	*Temp:*	66		
SG Corr Factor:	.999			*Time:*	930

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	686.6	3	0.06	4	5.11	13.6	
Notch #6	690.8	3	0.06	4	5.11	13.5	
Notch #6	694.2	3	0.06	4	5.15	13.5	
Notch #6	696.2	3	0.06	4	5.15	13.6	
Notch #6	698.2	3	0.06	4	5.15	13.5	
Notch #6	699.6	3	0.06	4	5.12	13.6	
Notch #6	699.6	3	0.06	4	5.11	13.6	
Notch #6	702	3	0.06	4	5.13	13.6	
#DIV/0!	**695.900**	**3.000**	**.060**	**4.000**	**5.129**	**13.563**	Mean
#DIV/0!	**5.146**	**.000**	**.000**	**.000**	**.019**	**.052**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.00E-06	0.0006	.051	.136	29.363	126,221	4,511

Performance factor adjusted for fuel density: 4,506

****% Change PF= 0.95 %**

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

Company Name:	Willamette & Pacific	Location	Albany, OR		Date:	2/7/95
Test Portion:	Baseline	Stack Diam.	24	Inches		
Engine Type:	645E	Mile/Hrs				
Equipment Type:	Locomotive	ID #:	2311		Baro	30.13
Fuel Sp. Gravity(SG	.855	Temp:				
					Time:	945

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	697	6.2	0.08	8	4.94	13.5	
Notch #8	702	6.2	0.08	8	4.94	13.6	
Notch #8	700	6.25	0.08	8	4.94	13.5	
Notch #8	702	6.25	0.08	8	4.94	13.6	
Notch #8	704	6.25	0.08	8	4.92	13.6	
Notch #8	701	6.25	0.08	8	4.98	13.5	
Notch #8	700	6.25	0.08	5	4.98	13.5	
Notch #8	699	6.25	0.07	8	4.94	13.5	
Notch #8	699	6.25	0.07	5	4.94	13.5	
#DIV/0!	**700.444**	**6.239**	**.078**	**7.333**	**4.947**	**13.533**	Mean
#DIV/0!	**2.068**	**.022**	**.004**	**1.323**	**.020**	**.050**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
7.33E-06	0.000777778	.049	.135	29.333	130,158	3,258

Company Name:	Willamette & Pacific	Location:	Albany, OR		Test Date:	3/8/95
Test Portion:	Treated	Stack Diam:	24	Inches		
Engine Type:	645E	Mile/Hrs:				
Equipment Type	Locomotive	ID #:	2311		Baro:	29.64
Fuel Sp. Gravity:	.856	Temp:	66			
SG Corr Factor:	.999				Time:	930

RPM	Exh Temp	Pv Inch	CO	4	CO2	O2	
Notch #8	686.2	6.3	0.07	4	4.84	13.9	
Notch #8	682.6	6.4	0.07	4	4.82	13.9	
Notch #8	683.6	6.4	0.07	4	4.82	13.9	
Notch #8	684.6	6.4	0.07	4	4.78	13.9	
Notch #8	683.6	6.4	0.07	6	4.84	14	
Notch #8	683.6	6.4	0.07	6	4.88	14	
Notch #8	683.2	6.4	0.06	6	4.88	14	
Notch #8	682.2	6.4	0.07	6	4.88	14	
#DIV/0!	**683.700**	**6.388**	**.069**	**5.000**	**4.843**	**13.950**	Mean
#DIV/0!	**1.242**	**.035**	**.004**	**1.069**	**.036**	**.053**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
5.00E-06	0.0006875	.048	.140	29.333	133,194	3,245

Performance factor adjusted for fuel density: 3,241

****% Change PF= -0.53 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2301	*Baro*	30.00
Fuel Sp. Gravity(SG	.855	*Temp:*			
				Time:	1530

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	193.4	0.15	0.01	2	0.52	19.9	
Idle	194	0.15	0.01	2	0.51	20	
Idle	194	0.15	0.01	2	0.51	20	
Idle	194	0.15	0.01	2	0.51	20	
Idle	193.6	0.15	0.01	2	0.51	20	
Idle	193.6	0.15	0.01	2	0.52	20	
Idle	193.8	0.15	0.01	2	0.51	20	
Idle	193.8	0.15	0.01	2	0.51	20	
#DIV/0!	**193.775**	**.150**	**.010**	**2.000**	**.513**	**19.988**	Mean
#DIV/0!	**.225**	**.000**	**.000**	**.000**	**.005**	**.035**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
2.00E-06	0.0001	.005	.200	28.882	1,230,481	148,796

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2301	*Baro:*	29.15
Fuel Sp. Gravity:	.858	*Temp:*	63.6		
SG Corr Factor:	.996			*Time:*	1425

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	189.6	0.15	0.01	4	0.49	19.7	
Idle	189.2	0.15	0.01	4	0.49	19.7	
Idle	186	0.1	0.01	4	0.49	19.7	
Idle	190	0.1	0.01	4	0.5	19.8	
Idle	190.2	0.1	0.01	4	0.49	19.8	
Idle	190.1	0.1	0.01	4	0.5	19.9	
Idle	190	0.1	0.01	4	0.5	19.9	
Idle	189.8	0.1	0.01	4	0.49	20	
#DIV/0!	**189.363**	**.113**	**.010**	**4.000**	**.494**	**19.813**	Mean
#DIV/0!	**1.396**	**.023**	**.000**	**.000**	**.005**	**.113**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.00E-06	0.0001	.005	.198	28.872	1,272,498	174,555

Performance factor adjusted for fuel density: 173,943

****% Change PF= 16.90 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2301	*Baro*	30.00
Fuel Sp. Gravity(SG	.855	*Temp:*		*Time:*	1530

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	287	1.3	0.01	2	1.66	18.1	
Notch #2	290	1.3	0.01	2	1.66	18.1	
Notch #2	290	1.3	0.01	2	1.69	18.2	
Notch #2	292	1.35	0.01	2	1.71	18.2	
Notch #2	293	1.35	0.01	2	1.7	18.2	
Notch #2	294	1.35	0.01	2	1.72	18.2	
Notch #2	297	1.35	0.01	3	1.72	18.2	
Notch #2	298	1.35	0.01	3	1.72	18.2	
Notch #2	300	1.35	0.01	2	1.7	18.2	
#DIV/0!	**293.444**	**1.333**	**.010**	**2.222**	**1.698**	**18.178**	Mean
#DIV/0!	**4.246**	**.025**	**.000**	**.441**	**.024**	**.044**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
2.22E-06	0.0001	.017	.182	28.999	378,609	16,485

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2301	*Baro:*	29.15
Fuel Sp. Gravity:	.858	*Temp:*			
SG Corr Factor:	.996			*Time:*	1425

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	312.8	1	0.01	3	1.82	18.1	
Notch #2	308.6	1	0.01	3	1.78	18.1	
Notch #2	307	1	0.01	4	1.77	18.2	
Notch #2	306.2	1	0.01	5	1.77	18.2	
Notch #2	306.6	1.1	0.01	4	1.78	18.2	
Notch #2	37.2	1.1	0.01	4	1.78	18.2	
Notch #2	308	1.1	0.01	4	1.79	18.2	
Notch #2	308.4	1.1	0.01	4	1.78	18.2	
#DIV/0!	**274.350**	**1.050**	**.010**	**3.875**	**1.784**	**18.175**	Mean
#DIV/0!	**95.845**	**.053**	**.000**	**.641**	**.016**	**.046**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
3.88E-06	0.0001	.018	.182	29.013	360,436	17,210

Performance factor adjusted for fuel density: 17,150

****% Change PF= 4.03 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2301	*Baro*	30.00
Fuel Sp. Gravity(SG	.855	*Temp:*			
				Time:	1530

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	431	2	0	2	3.2	16.1	
Notch #4	432	2	0	3	3.2	16	
Notch #4	436	2	0.01	2	3.16	16	
Notch #4	440	2	0	3	3.15	16.1	
Notch #4	441	2.2	0	3	3.23	16	
Notch #4	447	2.2	0	2	3.27	16	
Notch #4	449	2.2	0	2	3.27	16	
Notch #4	449	2.2	0	2	3.24	16	
Notch #4	449	2.2	0	2	3.2	16.1	
Notch #4	449	2.2	0	2	3.21	16.1	
#DIV/0!	**442.300**	**2.120**	**.001**	**2.300**	**3.213**	**16.040**	Mean
#DIV/0!	**7.319**	**.103**	**.003**	**.483**	**.041**	**.052**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
2.30E-06	0.00001	.032	.160	29.156	202,341	7,646

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2301	*Baro:*	29.15
Fuel Sp. Gravity:	.858	*Temp:*	63.6		
SG Corr Factor:	.996			*Time:*	1425

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	476.2	1.85	0	4	3.39	15.8	
Notch #4	475.2	1.85	0	4	3.36	15.9	
Notch #4	471.6	1.85	0	4	3.19	16.1	
Notch #4	467.2	1.85	0.01	5	3.28	16	
Notch #4	468.6	1.9	0.01	5	3.26	16	
Notch #4	472.6	1.9	0.01	5	3.23	16	
Notch #4	471.4	1.9	0.01	5	3.37	15.9	
Notch #4	472.2	1.9	0	5	3.25	16	
Notch #4	469	1.9	0	5	3.27	16	
Notch #4	467	1.9	0	5	3.22	16.1	
#DIV/0!	**471.100**	**1.880**	**.004**	**4.700**	**3.282**	**15.980**	Mean
#DIV/0!	**3.150**	**.026**	**.005**	**.483**	**.068**	**.092**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.70E-06	0.00004	.033	.160	29.165	197,876	7,951

Performance factor adjusted for fuel density: 7,923

****% Change PF= 3.62 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2301	*Baro*	30.00
Fuel Sp. Gravity(SG	.855	*Temp:*			
				Time:	1530

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	680	3.2	0.03	5	5.5	13	
Notch #6	682	3.2	0.03	5	5.53	12.9	
Notch #6	684	3.2	0.03	6	5.53	12.9	
Notch #6	685	3	0.03	5	5.55	12.8	
Notch #6	689	3	0.03	5	5.5	12.9	
Notch #6	688	3	0.03	5	5.53	12.9	
Notch #6	688	3	0.03	6	5.5	12.9	
Notch #6	688	3	0.03	5	5.53	12.8	
#DIV/0!	**685.500**	**3.075**	**.030**	**5.250**	**5.521**	**12.888**	Mean
#DIV/0!	**3.295**	**.104**	**.000**	**.463**	**.019**	**.064**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
5.25E-06	0.0003	.055	.129	29.399	118,110	4,176

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2301	*Baro:*	29.15
Fuel Sp. Gravity:	.858	*Temp:*	63.6		
SG Corr Factor:	.996			*Time:*	1425

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	724.6	2.6	0.06	6	5.79	12.2	
Notch #6	722	2.6	0.04	6		12.6	
Notch #6	717.8	2.6	0.05	6	5.73	12.4	
Notch #6	728.6	2.6	0.05	6	5.73	12.4	
Notch #6	729	2.6	0.05	6	5.77	12.4	
Notch #6	731	2.6	0.05	6	5.75	12.4	
Notch #6	734.6	2.6	0.06	6	5.77	12.3	
Notch #6	734.6	2.6	0.06	6	5.75	12.3	
#DIV/0!	**727.775**	**2.600**	**.053**	**6.000**	**5.756**	**12.375**	Mean
#DIV/0!	**5.960**	**.000**	**.007**	**.000**	**.022**	**.116**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.00E-06	0.000525	.058	.124	29.416	112,943	4,359

Performance factor adjusted for fuel density: 4,343

****% Change PF= 4.02 %**

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

Company Name:	Willamette & Pacific	Location	Albany, OR	Date:	2/7/95
Test Portion:	Baseline	Stack Diam.	24 Inches		
Engine Type:	645E	Mile/Hrs			
Equipment Type:	Locomotive	ID #:	2301	Baro	30.00
Fuel Sp. Gravity(SG	.855	Temp:		Time:	1530

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	774	6.2	0.05	6	6.25	12.1	
Notch #8	774	6.2	0.05	6	6.22	12.1	
Notch #8	774	6.2	0.06	6	6.22	12.1	
Notch #8	774	6.4	0.05	5	6.2	12.2	
Notch #8	774	6.4	0.05	4	6.17	12.3	
Notch #8	774	6.4	0.05	4	6.16	12.3	
Notch #8	774	6.4	0.05	5	6.16	12.3	
Notch #8	774	6.4	0.05	4	6.15	12.3	
Notch #8	773	6.4	0.05	4	6.16	12.3	
Notch #8	772	6.4	0.05	4	6.15	12.3	
#DIV/0!	773.700	6.340	.051	4.800	6.184	12.230	Mean
#DIV/0!	.675	.097	.003	.919	.036	.095	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.80E-06	0.00051	.062	.122	29.479	105,454	2,694

Company Name:	Willamette & Pacific	Location:	Albany, OR	Test Date:	3/9/95
Test Portion:	Treated	Stack Diam:	24 Inches		
Engine Type:	645E	Mile/Hrs:			
Equipment Type	Locomotive	ID #:	2301	Baro:	29.15
Fuel Sp. Gravity:	.858	Temp:	63.6		
SG Corr Factor:	.996			Time:	1425

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	752	6.2	0.04	4	5.88	12.1	
Notch #8	752	6.2	0.04	4	5.84	12.1	
Notch #8	752	6.2	0.04	4	5.84	12.2	
Notch #8	751.8	6.2	0.04	4	5.84	12.2	
Notch #8	751.8	6.2	0.04	4	5.84	12.2	
Notch #8	751.6	6.2	0.04	5	5.83	12.2	
Notch #8	751.6	6	0.04	4	5.83	12.2	
Notch #8	751.6	6	0.04	4	5.82	12.2	
#DIV/0!	751.800	6.150	.040	4.125	5.840	12.175	Mean
#DIV/0!	.185	.093	.000	.354	.018	.046	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.13E-06	0.0004	.058	.122	29.422	111,609	2,829

Performance factor adjusted for fuel density: 2,819

****% Change PF= 4.61 %**

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

Company Name:	Willamette & Pacific	Location	Albany, OR	Date:	2/7/95
Test Portion:	Baseline	Stack Diam.	24 Inches		
Engine Type:	645E	Mile/Hrs			
Equipment Type:	Locomotive	ID #:	2302	Baro	29.98
Fuel Sp. Gravity(SG	.855	Temp:	74		
				Time:	1630

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	190	0.2	0	4	0.49	19.9	
Idle	190	0.25	0	4	0.49	19.9	
Idle	190	0.25	0	4	0.49	19.8	
Idle	190	0.25	0.01	5	0.49	19.8	
Idle	190	0.25	0	4	0.49	19.8	
Idle	189	0.25	0.01	4	0.49	19.8	
Idle	188	0.3	0	4	0.49	19.8	
Idle	188	0.3	0	4	0.49	19.8	
#DIV/0!	**189.375**	**.256**	**.003**	**4.125**	**.490**	**19.825**	Mean
#DIV/0!	**.916**	**.032**	**.005**	**.354**	**.000**	**.046**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.13E-06	0.000025	.005	.198	28.872	1,301,200	119,940

Company Name:	Willamette & Pacific	Location:	Albany, OR	Test Date:	3/8/95
Test Portion:	Treated	Stack Diam:	24 Inches		
Engine Type:	645E	Mile/Hrs:			
Equipment Type	Locomotive	ID #:	2302	Baro:	29.50
Fuel Sp. Gravity:	.856	Temp:	66.6		
SG Corr Factor:	.999			Time:	1455

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	165.2	0.25	0.02	4	0.48	19.6	
Idle	165.4	0.3	0.02	4	0.48	19.6	
Idle	165.4	0.3	0.02	4	0.48	19.6	
Idle	165.6	0.25	0.02	4	0.48	19.6	
Idle	165.6	0.25	0.02	4	0.48	19.6	
Idle	165.8	0.3	0.02	4	0.48	19.6	
Idle	166	0.3	0.02	4	0.48	19.6	
Idle	166.2	0.3	0.02	4	0.48	19.6	
#DIV/0!	**165.650**	**.281**	**.020**	**4.000**	**.480**	**19.600**	Mean
#DIV/0!	**.334**	**.026**	**.000**	**.000**	**.000**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.00E-06	0.0002	.005	.196	28.861	1,281,518	109,785

Performance factor adjusted for fuel density: 109,657

****% Change PF = -8.57 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2302	*Baro*	29.98
Fuel Sp. Gravity(SG	.855	*Temp:*	74		
				Time:	1630

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	320	1.2	0.01	6	1.96	18	
Notch #2	320	1.2	0.01	5	1.96	18	
Notch #2	319	1.2	0.01	5	1.96	18	
Notch #2	319	1.2	0.01	5	1.96	18	
Notch #2	318	1.2	0.01	5	1.93	18	
Notch #2	317	1.2	0.01	5	1.93	18	
Notch #2	317	1.15	0.01	5	1.93	18	
Notch #2	317	1.15	0.01	6	1.93	18	
Notch #2	318	1.15	0.01	6	1.93	18	
Notch #2	319	1.15	0.01	6	1.93	18	
#DIV/0!	**318.400**	**1.180**	**.010**	**5.400**	**1.942**	**18.000**	Mean
#DIV/0!	**1.174**	**.026**	**.000**	**.516**	**.015**	**.000**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw1**	**pf1**	**PF1**
5.40E-06	0.0001	.019	.180	29.031	331,297	15,581

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2302	*Baro:*	29.50
Fuel Sp. Gravity:	.856	*Temp:*	66.6		
SG Corr Factor:	.999			*Time:*	1455

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	314	1.4	0.01	6	1.77	18	
Notch #2	314.4	1.4	0.01	6	1.76	18.1	
Notch #2	315.2	1.4	0.01	4	1.75	18.1	
Notch #2	316	1.4	0.01	4	1.75	18	
Notch #2	317	1.4	0.01	4	1.75	18	
Notch #2	317.6	1.4	0.01	4	1.75	18	
Notch #2	318.2	1.45	0.01	4	1.75	18.1	
Notch #2	318.4	1.45	0.01	4	1.75	18.1	
#DIV/0!	**316.350**	**1.413**	**.010**	**4.500**	**1.754**	**18.050**	Mean
#DIV/0!	**1.706**	**.023**	**.000**	**.926**	**.007**	**.053**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw2**	**pf2**	**PF2**
4.50E-06	0.0001	.018	.181	29.003	366,351	15,600

Performance factor adjusted for fuel density: 15,582

****% Change PF= 0.01** %

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

Company Name:	Willamette & Pacific	Location	Albany, OR		Date:	2/7/95
Test Portion:	Baseline	Stack Diam.	24	Inches		
Engine Type:	645E	Mile/Hrs				
Equipment Type:	Locomotive	ID #:	2302		Baro	29.98
Fuel Sp. Gravity(SG	.855	Temp:				
					Time:	1630

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	481	2	0.01	4	3.57	15.7	
Notch #4	487	2	0.01	4	3.57	15.7	
Notch #4	489	2	0.01	4	3.57	15.7	
Notch #4	492	2	0.01	3	3.61	15.6	
Notch #4	497	2	0.01	4	3.6	15.7	
Notch #4	497	2	0.01	4	3.6	15.7	
Notch #4	497	2	0.01	4	3.6	15.7	
Notch #4	497	2	0.01	4	3.6	15.7	
Notch #4	496	2	0.01	4	3.6	15.7	
Notch #4	496	2	0.01	4	3.6	15.7	
#DIV/0!	**492.900**	**2.000**	**.010**	**3.900**	**3.592**	**15.690**	Mean
#DIV/0!	**5.567**	**.000**	**.000**	**.316**	**.015**	**.032**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
3.90E-06	0.0001	.036	.157	29.203	180,792	7,226

Company Name:	Willamette & Pacific	Location:	Albany, OR		Test Date:	3/8/95
Test Portion:	Treated	Stack Diam:	24	Inches		
Engine Type:	645E	Mile/Hrs:				
Equipment Type	Locomotive	ID #:	2302		Baro:	29.50
Fuel Sp. Gravity:	.856	Temp:	66.6			
SG Corr Factor:	.999				Time:	1455

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	512.6	2.4	0.01	4	3.23	16	
Notch #4	511.8	2.4	0.01	3	3.23	16	
Notch #4	510.8	2.4	0.01	4	3.22	16	
Notch #4	510.2	2.4	0.01	3	3.22	16	
Notch #4	509.4	2.4	0.01	4	3.22	16	
Notch #4	508.4	2.5	0.01	4	3.2	16	
Notch #4	506	2.5	0.01	4	3.17	16.1	
Notch #4	505	2.5	0.01	4	3.17	16.1	
#DIV/0!	**509.275**	**2.438**	**.010**	**3.750**	**3.208**	**16.025**	Mean
#DIV/0!	**2.683**	**.052**	**.000**	**.463**	**.025**	**.046**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
3.75E-06	0.0001	.032	.160	29.154	202,053	7,318

Performance factor adjusted for fuel density: 7,310

****% Change PF= 1.16** %

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/7/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2302	*Baro*	29.98
Fuel Sp. Gravity(SG	.855	*Temp:*	74		
				Time:	1630

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	665	3	0.04	4	5.09	13.6	
Notch #6	666	3	0.04	4	5.12	13.6	
Notch #6	666	3	0.04	4	5.12	13.6	
Notch #6	667	3	0.04	4	5.09	13.6	
Notch #6	668	3	0.04	4	5.09	13.6	
Notch #6	668	3	0.04	4	5.12	13.6	
Notch #6	670	3	0.04	4	5.13	13.5	
Notch #6	671	3	0.04	4	5.12	13.6	
Notch #6	670	3	0.04	4	5.13	13.5	
Notch #6	673	3	0.04	4	5.12	13.6	
#DIV/0!	**668.400**	**3.000**	**.040**	**4.000**	**5.113**	**13.580**	Mean
#DIV/0!	**2.547**	**.000**	**.000**	**.000**	**.016**	**.042**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw1**	**pf1**	**PF1**
4.00E-06	0.0004	.051	.136	29.362	127,088	4,513

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2302	*Baro:*	29.50
Fuel Sp. Gravity:	.856	*Temp:*	66.6		
SG Corr Factor:	.999			*Time:*	

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	681.2	3.4	0.05	10	4.87	13.7	
Notch #6	682.4	3.4	0.05	10	4.85	13.7	
Notch #6	681.6	3.4	0.05	10	4.81	13.7	
Notch #6	681.8	3.4	0.05	10	4.83	13.7	
Notch #6	683.8	3.4	0.05	10	4.83	13.7	
Notch #6	684.6	3.4	0.05	10	4.8	13.7	
Notch #6	684.4	3.4	0.05	10	4.76	13.7	
Notch #6	683.6	3.4	0.05	10	4.77	13.7	
#DIV/0!	**682.925**	**3.400**	**.050**	**10.000**	**4.815**	**13.700**	Mean
#DIV/0!	**1.335**	**.000**	**.000**	**.000**	**.038**	**.000**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw2**	**pf2**	**PF2**
1.00E-05	0.0005	.048	.137	29.319	134,307	4,473

Performance factor adjusted for fuel density: 4,467

****% Change PF= -1.01 %**

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

Company Name:	Willamette & Pacific	Location	Albany, OR		Date:	2/7/95
Test Portion:	Baseline	Stack Diam.	24	Inches		
Engine Type:	645E	Mile/Hrs				
Equipment Type:	Locomotive	ID #:	2302		Baro	29.98
Fuel Sp. Gravity(SG	.855	Temp:				
					Time:	1630

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	695	6.2	0.02	5	5.25	13.4	
Notch #8	693	6.2	0.02	4	5.27	13.3	
Notch #8	693	6.2	0.02	4	5.28	13.3	
Notch #8	693	6.2	0.02	4	5.25	13.4	
Notch #8	696	6.2	0.03	5	5.19	13.5	
Notch #8	696	6.2	0.03	5	5.23	13.4	
Notch #8	695	6.2	0.02	5	5.21	13.4	
Notch #8	693	6.2	0.02	5	5.25	13.4	
Notch #8	693	6.2	0.02	5	5.25	13.4	
Notch #8	691	6.2	0.02	5	5.25	13.4	
#DIV/0!	**693.800**	**6.200**	**.022**	**4.700**	**5.243**	**13.390**	Mean
#DIV/0!	**1.619**	**.000**	**.004**	**.483**	**.027**	**.057**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.70E-06	0.00022	.052	.134	29.375	124,432	3,108

Company Name:	Willamette & Pacific	Location:	Albany, OR		Test Date:	3/8/95
Test Portion:	Treated	Stack Diam:	24	Inches		
Engine Type:	645E	Mile/Hrs:				
Equipment Type	Locomotive	ID #:	2302		Baro:	29.50
Fuel Sp. Gravity:	.856	Temp:	66.6			
SG Corr Factor:	.999				Time:	1455

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	694.2	6.8	0.02	4	4.97	13.8	
Notch #8	694.2	6.8	0.02	4	4.99	13.7	
Notch #8	698.2	7	0.03	5	4.9	13.8	
Notch #8	697.4	7	0.02	4	5.02	13.8	
Notch #8	695.6	7	0.02	4	4.93	13.8	
Notch #8	694.2	7	0.02	4	4.93	13.7	
Notch #8	692.6	7	0.02	4	4.94	13.7	
Notch #8	694.6	7	0.02	4	4.95	13.7	
#DIV/0!	**695.125**	**6.950**	**.021**	**4.125**	**4.954**	**13.750**	Mean
#DIV/0!	**1.855**	**.093**	**.004**	**.354**	**.038**	**.053**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.13E-06	0.0002125	.050	.138	29.343	131,547	3,080

Performance factor adjusted for fuel density: 3,077

****% Change PF= -1.01 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2315	*Baro*	30.24
Fuel Sp. Gravity(SG	.857	*Temp:*	61		
				Time:	1000

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	164.2	0.1	0.01	6	0.44	20.2	
Idle	164	0.1	0.02	6	0.44	20.3	
Idle	164.2	0.1	0.02	6	0.44	20.3	
Idle	164.2	0.1	0.02	8	0.44	20.3	
#DIV/0!	**164.150**	**.100**	**.018**	**6.500**	**.440**	**20.275**	Mean
#DIV/0!	**.100**	**.000**	**.005**	**1.000**	**.000**	**.050**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
6.50E-06	0.000175	.004	.203	28.882	1,396,048	202,826

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2315	*Baro:*	29.11
Fuel Sp. Gravity:	.855	*Temp:*	70.6		
SG Corr Factor:	1.002			*Time:*	935

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	193.6	0.05	0.01	4	0.45	20	
Idle	192.6	0.05	0.01	4	0.46	20	
Idle	192.6	0.05	0.01	4	0.45	20	
Idle	193.2	0.1	0.01	3	0.44	20.1	
Idle	191.4	0.1	0.01	4	0.43	20.1	
Idle	192.4	0.1	0.01	4	0.44	20.1	
Idle	192.4	0.1	0.01	4	0.44	20.1	
Idle	192.4	0.1	0.01	4	0.44	20.1	
#DIV/0!	**192.575**	**.081**	**.010**	**3.875**	**.444**	**20.063**	Mean
#DIV/0!	**.645**	**.026**	**.000**	**.354**	**.009**	**.052**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
3.88E-06	0.0001	.004	.201	28.874	1,412,276	228,367

Performance factor adjusted for fuel density: 228,900

****% Change PF= 12.85 %**

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

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2315	*Baro*	30.24
Fuel Sp. Gravity(SG	.857	*Temp:*			
				Time:	1000

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	301	1.3	0	6	1.82	18.5	
Notch #2	301.8	1.3	0	6	1.81	18.5	
Notch #2	302.6	1.3	0	6	1.82	18.5	
Notch #2	303.8	1.35	0	6	1.8	18.5	
#DIV/0!	**302.300**	**1.313**	**.000**	**6.000**	**1.813**	**18.500**	Mean
#DIV/0!	**1.194**	**.025**	**.000**	**.000**	**.010**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
6.00E-06	0	.018	.185	29.030	356,662	15,807

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2315	*Baro:*	29.11
Fuel Sp. Gravity:	.855	*Temp:*	70.6		
SG Corr Factor:	1.002			*Time:*	935

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	319.2	1	0	4	1.85	18	
Notch #2	324.6	1	0	2	1.87	18	
Notch #2	325.6	1	0	4	1.88	18	
Notch #2	325	1	0.01	3	1.86	18	
Notch #2	322.4	1.1	0.01	3	1.84	18	
Notch #2	322	1.1	0.01	3	1.84	18	
Notch #2	322.2	1.1	0.01	4	1.84	18	
Notch #2	322.4	1.1	0.01	4	1.84	18	
#DIV/0!	**322.925**	**1.050**	**.006**	**3.375**	**1.853**	**18.000**	Mean
#DIV/0!	**2.073**	**.053**	**.005**	**.744**	**.016**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
3.38E-06	0.0000625	.019	.180	29.017	347,956	17,143

Performance factor adjusted for fuel density: 17,183

****% Change PF= 8.71 %**

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

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2315	*Baro*	30.24
Fuel Sp. Gravity(SG	.857	*Temp:*			
				Time:	1000

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	470.6	2	0.01	6	3.36	16.6	
Notch #4	469.4	2.2	0	6	3.33	16.6	
Notch #4	466.6	2.1	0	6	3.31	16.7	
Notch #4	467.6	2.1	0	6	3.3	16.7	
#DIV/0!	**468.550**	**2.100**	**.003**	**6.000**	**3.325**	**16.650**	Mean
#DIV/0!	**1.792**	**.082**	**.005**	**.000**	**.026**	**.058**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
6.00E-06	0.000025	.033	.167	29.198	195,588	7,563

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2315	*Baro:*	29.11
Fuel Sp. Gravity:	.855	*Temp:*	70.6		
SG Corr Factor:	1.002			*Time:*	935

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	479.4	1.85	0.01	4	3.39	15.8	
Notch #4	485.6	1.85	0.01	3	3.39	15.9	
Notch #4	491.4	1.85	0.01	3	3.43	15.8	
Notch #4	491.4	1.85	0.01	4	3.42	15.8	
Notch #4	491	1.85	0.01	5	3.43	15.8	
Notch #4	490.4	1.85	0.01	3	3.42	15.8	
Notch #4	489	1.85	0.01	4	3.38	15.8	
Notch #4	489	1.85	0.01	4	3.39	15.8	
#DIV/0!	**488.400**	**1.850**	**.010**	**3.750**	**3.406**	**15.813**	Mean
#DIV/0!	**4.111**	**.000**	**.000**	**.707**	**.021**	**.035**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
3.75E-06	0.0001	.034	.158	29.178	190,458	7,781

Performance factor adjusted for fuel density: 7,799

****% Change PF= 3.11 %**

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

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2315	*Baro*	30.24
Fuel Sp. Gravity(SG	.857	*Temp:*		*Time:*	1000

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	656.6	3.2	0.03	6	5.01	14.3	
Notch #6	655.4	3.2	0.03	6	4.89	14.5	
Notch #6	620.2	3.2	0.02	6	4.29	15	
Notch #6	615.2	3.2	0.01	5	4.26	15	
Notch #6	620.6	3.2	0.01	5	4.33	15	
#DIV/0!	**633.600**	**3.200**	**.020**	**5.600**	**4.556**	**14.760**	Mean
#DIV/0!	**20.563**	**.000**	**.010**	**.548**	**.363**	**.336**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
5.60E-06	0.0002	.046	.148	29.320	142,868	4,857

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2315	*Baro:*	
Fuel Sp. Gravity:		*Temp:*			
SG Corr Factor:	#VALUE!			*Time:*	

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
#DIV/0!	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	Mean
#DIV/0!	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Performance factor adjusted for fuel density: #DIV/0!

****% Change PF= ##### %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2315	*Baro*	30.24
Fuel Sp. Gravity(SG	.857	*Temp:*		*Time:*	1000

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	675.4	4.4	0.02	8	5.03	14	
Notch #8	675.2	4.4	0.02	8	5.05	14	
Notch #8	675.2	4.6	0.02	8	5.05	14.1	
Notch #8	675.6	4.6	0.02	8	5.05	14.1	
#DIV/0!	**675.350**	**4.500**	**.020**	**8.000**	**5.045**	**14.050**	Mean
#DIV/0!	**.191**	**.115**	**.000**	**.000**	**.010**	**.058**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
8.00E-06	0.0002	.050	.141	29.370	129,266	3,776

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/9/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2315	*Baro:*	29.11
Fuel Sp. Gravity:	.855	*Temp:*	70.6		
SG Corr Factor:	1.002			*Time:*	935

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	689.4	4	0.02	4	5.17	13.4	
Notch #8	689	4	0.02	4	5.12	13.4	
Notch #8	689	4	0.02	4	5.12	13.4	
Notch #8	689	4	0.02	4	5.11	13.4	
Notch #8	689.2	3.8	0.02	5	5.1	13.5	
Notch #8	690	3.8	0.02	4	5.03	13.5	
Notch #8	687.6	4	0.02	4	5.17	13.4	
Notch #8	690.2	4	0.02	5	5.16	13.4	
Notch #8	688.2	4	0.02	4	4.99	13.4	
Notch #8	692.4	4	0.02	5	5.09	13.2	
Notch #8	692.8	4	0.02	5	5.07	13.2	
Notch #8	693	4	0.02	5	5.07	13.2	
Notch #8	693.2	4	0.02	5	5.07	13.3	
Notch #8	693.2	4	0.02	5	5.07	13.3	
#DIV/0!	**690.443**	**3.971**	**.020**	**4.500**	**5.096**	**13.357**	Mean
#DIV/0!	**2.026**	**.073**	**.000**	**.519**	**.052**	**.102**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.50E-06	0.0002	.051	.134	29.350	127,955	3,929

Performance factor adjusted for fuel density: 3,939

****% Change PF= 4.31 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2308	*Baro*	30.17
Fuel Sp. Gravity(SG	.856	*Temp:*			
				Time:	1645

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	185.6	0.1	0.01	4	0.49	20	
Idle	185.4	0.1	0.01	4	0.49	20	
Idle	185.2	0.1	0.01	4	0.49	20	
Idle	185.2	0.1	0.01	4	0.49	20	
Idle	184.8	0.1	0.01	4	0.5	20.1	
Idle	184.8	0.1	0.01	4	0.5	20.1	
Idle	184.8	0.1	0.01	4	0.5	20.1	
Idle	184.8	0.1	0.01	4	0.5	20.1	
#DIV/0!	**185.075**	**.100**	**.010**	**4.000**	**.495**	**20.050**	Mean
#DIV/0!	**.320**	**.000**	**.000**	**.000**	**.005**	**.053**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.00E-06	0.0001	.005	.201	28.881	1,269,791	187,333

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2308	*Baro:*	29.50
Fuel Sp. Gravity:	.852	*Temp:*	75.8		
SG Corr Factor:	1.005			*Time:*	1645

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	189	0.15	0.01	3	0.49	20.3	
Idle	186.8	0.1	0.01	3	0.49	20.4	
Idle	186.6	0.1	0.01	3	0.49	20.4	
Idle	186.6	0.1	0.01	3	0.49	20.4	
Idle	186.6	0.15	0.01	4	0.49	20.4	
Idle	186.6	0.15	0.01	4	0.49	20.4	
Idle	186.6	0.1	0.01	3	0.49	20.4	
Idle	186.6	0.1	0.01	3	0.49	20.4	
#DIV/0!	**186.925**	**.119**	**.010**	**3.250**	**.490**	**20.388**	Mean
#DIV/0!	**.841**	**.026**	**.000**	**.463**	**.000**	**.035**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
3.25E-06	0.0001	.005	.204	28.894	1,284,214	172,166

Performance factor adjusted for fuel density: 172,970

****% Change PF= -7.67 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2308	*Baro*	30.17
Fuel Sp. Gravity(SG	.856	*Temp:*			
				Time:	1650

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	326	1.25	0.01	4	2.09	18	
Notch #2	327.8	1.25	0.01	4	2.09	18	
Notch #2	328.8	1.25	0.01	4	2.08	18	
Notch #2	329.8	1.2	0.01	4	2.08	18	
Notch #2	330.4	1.2	0.01	4	2.08	18	
Notch #2	331	1.2	0.01	4	2.08	18	
Notch #2	331.8	1.2	0.01	4	2.09	18	
Notch #2	332.2	1.2	0.01	4	2.09	18	
#DIV/0!	**329.725**	**1.219**	**.010**	**4.000**	**2.085**	**18.000**	Mean
#DIV/0!	**2.103**	**.026**	**.000**	**.000**	**.005**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.00E-06	0.0001	.021	.180	29.054	309,095	14,453

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2308	*Baro:*	29.50
Fuel Sp. Gravity:	.852	*Temp:*	75.8		
SG Corr Factor:	1.005			*Time:*	1645

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	321.6	1.25	0.01	6	1.99	18.5	
Notch #2	323	1.25	0.01	6	1.99	18.5	
Notch #2	325.4	1.25	0.01	6	1.98	18.5	
Notch #2	326.4	1.25	0.01	6	1.98	18.5	
Notch #2	327	1.25	0.01	6	1.99	18.5	
Notch #2	328.6	1.25	0.01	6	1.98	18.5	
Notch #2	329.6	1.25	0.01	6	1.99	18.5	
Notch #2	330.4	1.25	0.01	6	1.99	18.5	
#DIV/0!	**326.500**	**1.250**	**.010**	**6.000**	**1.986**	**18.500**	Mean
#DIV/0!	**3.093**	**.000**	**.000**	**.000**	**.005**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.00E-06	0.0001	.020	.185	29.058	324,206	14,771

Performance factor adjusted for fuel density: 14,840

****% Change PF= 2.68 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2308	*Baro*	30.17
Fuel Sp. Gravity(SG	.856	*Temp:*			
				Time:	1645

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	506.8	2.4	0.01	2	3.8	15.6	
Notch #4	510.6	2.4	0.01	3	3.81	15.5	
Notch #4	516.4	2.3	0.01	4	3.85	15.5	
Notch #4	516	2.4	0.01	3	3.78	15.6	
Notch #4	513.4	2.4	0.01	2	3.78	15.6	
Notch #4	512.8	2.4	0.01	4	3.8	15.6	
Notch #4	514	2.4	0.01	4	3.81	15.6	
Notch #4	516.2	2.4	0.01	4	3.84	15.5	
#DIV/0!	**513.275**	**2.388**	**.010**	**3.250**	**3.809**	**15.563**	Mean
#DIV/0!	**3.286**	**.035**	**.000**	**.886**	**.025**	**.052**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw1**	**pf1**	**PF1**
3.25E-06	0.0001	.038	.156	29.232	170,728	6,332

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2308	*Baro:*	29.50
Fuel Sp. Gravity:	.852	*Temp:*	75.8		
SG Corr Factor:	1.005			*Time:*	1645

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	522.2	2.6	0.01	6	3.74	15.2	
Notch #4	522.6	2.6	0.01	6	3.73	15.2	
Notch #4	522.6	2.5	0.01	6	3.73	15.2	
Notch #4	522.6	2.5	0.01	8	3.71	15.3	
Notch #4	522.8	2.5	0.01	6	3.71	15.3	
Notch #4	523	2.6	0.01	7	3.71	15.3	
Notch #4	521.6	2.6	0.01	6	3.64	15.3	
Notch #4	520.4	2.6	0.01	6	3.65	15.4	
#DIV/0!	**522.225**	**2.563**	**.010**	**6.375**	**3.703**	**15.275**	Mean
#DIV/0!	**.851**	**.052**	**.000**	**.744**	**.037**	**.071**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw2**	**pf2**	**PF2**
6.38E-06	0.0001	.037	.153	29.204	175,347	6,236

Performance factor adjusted for fuel density: 6,265

****% Change PF= -1.06 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2308	*Baro*	30.17
Fuel Sp. Gravity(SG	.856	*Temp:*			
				Time:	1650

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	675.4	3.6	0.05	2	5.34	13.4	
Notch #6	678.2	3.6	0.05	4	5.34	13.4	
Notch #6	679.4	3.6	0.05	4	5.34	13.4	
Notch #6	679.6	3.6	0.05	4	5.34	13.4	
Notch #6	679.8	3.6	0.05	6	5.4	13.4	
Notch #6	685	3.6	0.05	6	5.49	13.3	
Notch #6	688.4	3.6	0.05	4	5.4	13.3	
Notch #6	689.2	3.6	0.05	6	5.4	13.3	
Notch #6	688.2	3.6	0.05	6	5.4	13.4	
Notch #6	688.2	3.6	0.05	6	5.4	13.4	
#DIV/0!	**683.140**	**3.600**	**.050**	**4.800**	**5.385**	**13.370**	Mean
#DIV/0!	**5.175**	**.000**	**.000**	**1.398**	**.047**	**.048**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.80E-06	0.0005	.054	.134	29.397	120,630	3,948

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2308	*Baro:*	29.50
Fuel Sp. Gravity:	.852	*Temp:*	75.8		
SG Corr Factor:	1.005			*Time:*	1645

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	685.8	3.6	0.05	4	5.4	12.8	
Notch #6	689	3.6	0.06	4	5.4	12.8	
Notch #6	689.4	3.8	0.05	4	5.42	12.8	
Notch #6	690	3.8	0.06	5	5.4	12.8	
Notch #6	690.6	3.8	0.05	4	5.4	12.8	
Notch #6	691.4	3.8	0.05	4	5.42	12.8	
Notch #6	691.8	3.8	0.06	4	5.4	12.8	
Notch #6	692.4	3.8	0.05	4	5.42	12.8	
#DIV/0!	**690.050**	**3.750**	**.054**	**4.125**	**5.408**	**12.800**	Mean
#DIV/0!	**2.081**	**.093**	**.005**	**.354**	**.010**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.13E-06	0.0005375	.054	.128	29.377	119,982	3,816

Performance factor adjusted for fuel density: 3,834

****% Change PF= -2.89 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2308	*Baro*	30.17
Fuel Sp. Gravity(SG	.856	*Temp:*			
				Time:	1650

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	726	6.6	0.05	4	5.76	12.8	
Notch #8	725.2	6.6	0.05	4	5.76	12.9	
Notch #8	725.6	6.4	0.05	4	5.76	12.9	
Notch #8	725.4	6.6	0.05	4	5.76	12.9	
Notch #8	726.4	6.6	0.05	4	5.74	12.9	
Notch #8	726.2	6.6	0.05	4	5.74	12.9	
Notch #8	727.4	6.6	0.04	4	5.71	12.9	
Notch #8	725.8	6.5	0.04	4	5.7	13	
Notch #8	727.2	6.5	0.04	4	5.7	13	
Notch #8	725.4	6.5	0.04	4	5.7	13	
#DIV/0!	**726.060**	**6.550**	**.046**	**4.000**	**5.733**	**12.920**	Mean
#DIV/0!	**.755**	**.071**	**.005**	**.000**	**.028**	**.063**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
4.00E-06	0.00046	.057	.129	29.434	113,609	2,808

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2308	*Baro:*	29.50
Fuel Sp. Gravity:	.852	*Temp:*	75.8		
SG Corr Factor:	1.005			*Time:*	1645

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	736	6.6	0.05	6	5.78	12.2	
Notch #8	736.2	6.6	0.05	6	5.78	12.2	
Notch #8	736.2	6.6	0.05	6	5.78	12.2	
Notch #8	736.4	6.6	0.05	6	5.76	12.2	
Notch #8	736.6	6.8	0.05	6	5.74	12.2	
Notch #8	736.2	6.8	0.05	6	5.74	12.2	
Notch #8	736.4	6.8	0.05	6	5.73	12.2	
Notch #8	736.8	6.8	0.05	6	5.7	12.2	
#DIV/0!	**736.350**	**6.700**	**.050**	**6.000**	**5.751**	**12.200**	Mean
#DIV/0!	**.256**	**.107**	**.000**	**.000**	**.029**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.00E-06	0.0005	.058	.122	29.409	113,049	2,744

Performance factor adjusted for fuel density: 2,757

****% Change PF= -1.83 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2309	*Baro*	30.14
Fuel Sp. Gravity(SG	.857	*Temp:*		*Time:*	1815

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	189	0.15	0.02	6	0.5	20	
Idle	189.2	0.15	0.02	6	0.5	20.1	
Idle	190	0.15	0.02	6	0.5	20.1	
Idle	189.4	0.15	0.02	6	0.5	20.1	
Idle	189.2	0.15	0.02	6	0.5	20.1	
Idle	188.8	0.15	0.02	6	0.5	20.1	
Idle	188.6	0.15	0.02	6	0.5	20.1	
Idle	187	0.15	0.02	6	0.51	20	
#DIV/0!	**188.900**	**.150**	**.020**	**6.000**	**.501**	**20.075**	Mean
#DIV/0!	**.875**	**.000**	**.000**	**.000**	**.004**	**.046**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
6.00E-06	0.0002	.005	.201	28.884	1,227,486	148,224

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2309	*Baro:*	29.62
Fuel Sp. Gravity:	.857	*Temp:*	64		
SG Corr Factor:	1.000			*Time:*	1130

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Idle	181.2	0.1	0.02	6	0.52	20.2	
Idle	181.4	0.1	0.02	6	0.52	20.4	
Idle	181.4	0.15	0.02	6	0.52	20.4	
Idle	181.4	0.15	0.02	6	0.52	20.4	
Idle	181.6	0.15	0.02	6	0.53	20.4	
Idle	181.6	0.15	0.02	6	0.53	20.5	
Idle	181.6	0.15	0.02	6	0.53	20.5	
Idle	181.6	0.1	0.02	6	0.54	20.6	
#DIV/0!	**181.475**	**.131**	**.020**	**6.000**	**.526**	**20.425**	Mean
#DIV/0!	**.149**	**.026**	**.000**	**.000**	**.007**	**.116**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.00E-06	0.0002	.005	.204	28.902	1,172,431	149,179

Performance factor adjusted for fuel density: 149,179

****% Change PF= 0.64 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2309	*Baro*	30.14
Fuel Sp. Gravity(SG	.857	*Temp:*			
				Time:	1815

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	323.2	1.1	0.01	5	2.2	17.7	
Notch #2	328.8	1.1	0.01	5	2.19	17.6	
Notch #2	332.2	1.1	0.01	5	2.2	17.6	
Notch #2	327.6	1.1	0.01	6	2.24	17.6	
Notch #2	326	1.1	0.01	6	2.24	17.6	
Notch #2	326.6	1.1	0.01	6	2.26	17.6	
Notch #2	326.8	1.1	0.01	6	2.26	17.6	
Notch #2	327.4	1.1	0.01	6	2.26	17.6	
Notch #2		1.1	0.01	6	2.22	17.6	
Notch #2		1.1	0.01	6	2.24	17.6	
#DIV/0!	**327.325**	**1.100**	**.010**	**5.700**	**2.231**	**17.610**	Mean
#DIV/0!	**2.552**	**.000**	**.000**	**.483**	**.027**	**.032**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
5.70E-06	0.0001	.022	.176	29.062	288,918	14,191

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2309	*Baro:*	29.62
Fuel Sp. Gravity:	.857	*Temp:*	64		
SG Corr Factor:	1.000			*Time:*	1130

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #2	345.4	1	0.01	4	2.25	18.1	
Notch #2	343	1	0.01	4	2.24	18.2	
Notch #2	341.6	1	0.01	4	2.21	18.2	
Notch #2	340.6	1	0.01	4	2.23	18.2	
Notch #2	340.8	0.95	0.01	4	2.23	18.2	
Notch #2	342.4	1	0.01	4	2.2	18.2	
Notch #2	342.8	1	0.01	4	2.21	18.2	
Notch #2	343.6	1	0.01	4	2.21	18.2	
Notch #2	345	1	0.01	4	2.2	18.2	
Notch #2	345.4	0.95	0.01	4	2.21	18.2	
#DIV/0!	**343.060**	**.990**	**.010**	**4.000**	**2.219**	**18.190**	Mean
#DIV/0!	**1.789**	**.021**	**.000**	**.000**	**.017**	**.032**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.00E-06	0.0001	.022	.182	29.083	290,825	15,075

Performance factor adjusted for fuel density: 15,075

****% Change PF= 6.23 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2309	*Baro*	30.14
Fuel Sp. Gravity(SG	.857	*Temp:*			
				Time:	1815

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	525.2	1.9	0.02	5	3.81	15.5	
Notch #4	533.2	1.85	0.02	5	3.76	15.6	
Notch #4	536	1.85	0.02	5	3.81	15.6	
Notch #4	533.8	1.85	0.02	5	3.83	15.6	
Notch #4	534.8	1.85	0.02	4	3.81	15.6	
Notch #4	532.2	1.85	0.02	6	3.89	15.6	
Notch #4	531	1.85	0.02	6	3.96	15.5	
Notch #4	528.4	1.85	0.02	6	3.81	15.5	
Notch #4	533.4	1.85	0.02	6	3.83	15.6	
Notch #4	533.8	1.85	0.02	6	3.83	15.6	
#DIV/0!	**532.180**	**1.855**	**.020**	**5.400**	**3.834**	**15.570**	Mean
#DIV/0!	**3.226**	**.016**	**.000**	**.699**	**.055**	**.048**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
5.40E-06	0.0002	.038	.156	29.237	169,133	7,181

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2309	*Baro:*	29.62
Fuel Sp. Gravity:	.857	*Temp:*	64		
SG Corr Factor:	1.000			*Time:*	1130

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #4	525.8	1.75	0.02	6	3.92	15.9	
Notch #4	524.6	1.7	0.02	6	3.94	15.8	
Notch #4	525.2	1.7	0.02	5	3.93	15.8	
Notch #4	525.2	1.7	0.02	4	3.93	15.8	
Notch #4	524.2	1.7	0.01	4	3.93	15.7	
Notch #4	526	1.65	0.01	4	3.95	15.7	
Notch #4	527.8	1.7	0.01	5	3.95	15.7	
Notch #4	529.4	1.7	0.02	5	3.95	15.7	
#DIV/0!	**526.025**	**1.700**	**.016**	**4.875**	**3.938**	**15.763**	Mean
#DIV/0!	**1.745**	**.027**	**.005**	**.835**	**.012**	**.074**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.88E-06	0.0001625	.039	.158	29.261	165,020	7,233

Performance factor adjusted for fuel density: 7,233

****% Change PF= 0.72 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2309	*Baro*	30.14
Fuel Sp. Gravity(SG	.857	*Temp:*		*Time:*	1815

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	670	2.8	0.06	6	5.1	13.7	
Notch #6	672	2.8	0.06	6	5.05	13.7	
Notch #6	672.6	3	0.05	6	5.04	13.7	
Notch #6	674.8	3	0.05	6	5.02	13.8	
Notch #6	675.8	3	0.05	6	4.99	13.8	
Notch #6	675.4	3	0.05	6	4.99	13.6	
Notch #6	676	3	0.05	6	5.03	13.7	
Notch #6	679.8	3	0.05	6	5.01	13.8	
Notch #6	676.8	3	0.05	6	5.05	13.8	
Notch #6	681.8	3	0.05	6	5.05	13.8	
#DIV/0!	**675.500**	**2.960**	**.052**	**6.000**	**5.033**	**13.740**	Mean
#DIV/0!	**3.522**	**.084**	**.004**	**.000**	**.033**	**.070**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
6.00E-06	0.00052	.050	.137	29.355	128,727	4,629

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2309	*Baro:*	29.62
Fuel Sp. Gravity:	.857	*Temp:*	64		
SG Corr Factor:	1.000			*Time:*	1130

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #6	688.4	2.6	0.06	6	5.24	13.5	
Notch #6	690.4	2.6	0.07	6	5.24	13.5	
Notch #6	690.4	2.6	0.07	6	5.25	13.5	
Notch #6	691	2.6	0.07	6	5.27	13.5	
Notch #6	692.2	2.6	0.06	6	5.25	13.6	
Notch #6	693.2	2.6	0.07	6	5.28	13.6	
Notch #6	693.6	2.6	0.07	6	5.28	13.6	
Notch #6	694.2	2.6	0.07	6	5.27	13.7	
#DIV/0!	**691.675**	**2.600**	**.068**	**6.000**	**5.260**	**13.563**	Mean
#DIV/0!	**1.968**	**.000**	**.005**	**.000**	**.017**	**.074**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.00E-06	0.000675	.053	.136	29.384	122,994	4,711

Performance factor adjusted for fuel density: 4,711

****% Change PF= 1.78 %**

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

Company Name:	Willamette & Pacific	*Location*	Albany, OR	*Date:*	2/6/95
Test Portion:	Baseline	*Stack Diam.*	24 Inches		
Engine Type:	645E	*Mile/Hrs*			
Equipment Type:	Locomotive	*ID #:*	2309	*Baro*	30.14
Fuel Sp. Gravity(SG	.857	*Temp:*			
				Time:	1815

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	690.6	5.4	0.05	6	5.12	13.7	
Notch #8	690.8	5.4	0.05	6	5.09	13.7	
Notch #8	689.4	5.6	0.04	12	5.24	14	
Notch #8	686.4	5.6	0.04	13	5.26	13.9	
Notch #8	688	5.6	0.05	13	5.24	13.9	
Notch #8	687.8	5.6	0.05	13	5.26	13.9	
Notch #8	688.2	5.6	0.05	13	5.26	13.9	
Notch #8	688.6	5.6	0.05	13	5.25	13.9	
#DIV/0!	**688.725**	**5.550**	**.048**	**11.125**	**5.215**	**13.863**	Mean
#DIV/0!	**1.481**	**.093**	**.005**	**3.182**	**.069**	**.106**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw1**	**pf1**	**PF1**
1.11E-05	0.000475	.052	.139	29.390	124,456	3,287

Company Name:	Willamette & Pacific	*Location:*	Albany, OR	*Test Date:*	3/8/95
Test Portion:	Treated	*Stack Diam:*	24 Inches		
Engine Type:	645E	*Mile/Hrs:*			
Equipment Type	Locomotive	*ID #:*	2309	*Baro:*	29.62
Fuel Sp. Gravity:	.857	*Temp:*	64		
SG Corr Factor:	1.000			*Time:*	1130

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
Notch #8	691.2	5.2	0.05	8		13.6	
Notch #8	690.6	5.2	0.04	6	5.16	13.8	
Notch #8	690.4	5.2	0.04	6	5.13	13.8	
Notch #8	689	5.4	0.04	5	5.16	13.8	
Notch #8	688	5.4	0.04	5	5.14	13.8	
Notch #8	687.6	5.4	0.04	6	5.12	13.8	
Notch #8	687.4	5.6	0.04	6	5.12	13.8	
Notch #8	687.4	5.6	0.04	6	5.12	13.7	
#DIV/0!	**688.950**	**5.375**	**.041**	**6.000**	**5.136**	**13.763**	Mean
#DIV/0!	**1.578**	**.167**	**.004**	**.926**	**.018**	**.074**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw2**	**pf2**	**PF2**
6.00E-06	0.0004125	.051	.138	29.373	126,517	3,367

Performance factor adjusted for fuel density: 3,367

****% Change PF= 2.41 %**

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

10.0 APPENDIX 4

Figure 1
CARBON MASS BALANCE FORMULAE

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

DATA:

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

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

EQUATIONS:

Mwt =

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

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

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

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

FUEL ECONOMY:
PERCENT INCREASE (OR DECREASE)

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

Figure 2.

SAMPLE CALCULATION FOR THE CARBON MASS BALANCE

<u>BASELINE:</u>

Equation 1 (Volume Fractions)

VFHC = 13.20/1,000,000
= 0.0000132

VFCO = 0.017/100
= 0.00017

$VFCO_2$ = 1.937/100
= 0.01937

VFO_2 = 17.10/100
= 0.171

Equation 2 (Molecular Weight)

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

$$Mwt1 = 28.995$$

Equation 3 (Calculated Performance Factor)

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

$$pf1 = 329{,}809$$

Equation 4 (CFM Calculations)

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

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

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

CFM =2358.37

Equation 5 (Corrected Performance Factor)

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

PF1 = 108,115

TREATED:

Equation 1 (Volume Fractions)

VFHC = 14.6/1,000,000
= 0.0000146

VFCO = .013/100
= 0.00013

$VFCO_2$ = 1.826/100
= 0.01826

VFO_2 = 17.17/100
= 0.1717

Equation 2 (Molecular Weight)

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

$$Mwt2 = 28.980$$

Equation 3 (Calculated Performance Factor)

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

$$pf2 = 349,927$$

Equation 4 (CFM Calculations)

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

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

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

$$CFM = 2320.51$$

Equation 5 (Corrected Performance Factor)

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

$$= 115,966$$

Fuel Specific Gravity Correction Factor

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

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

PF2 = 115,966 x Specific Gravity Correction

PF2 = 115,966 x 1.0036

PF2 = 116,384

Equation 6 (Percent Change in Engine Performance Factor:)

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

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

= +7.65

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

11.0 APPENDIX 5

Abbreviated Resume -- December 1994

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Professor and Chair, Department of Mechanical Engineering
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Brigham Young University
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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

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

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

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

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

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

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

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

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

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

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

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

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.

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Patents

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

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

Figure 3. Barometric Pressure Readings from Corvallis, Oregon Area

Date	Time	Baro
2-6	8 AM	30.25
	9 AM	30.25
	10 AM	30.24
	11 AM	30.24
	1 PM	30.18
	3 PM	30.16
2-7	7 AM	30.14
	8 AM	30.14
	9 AM	30.13
	10 AM	30.13
	11 AM	30.12
	2 PM	30.00
3-8	7 AM	29.65
	8 AM	29.64
	9 AM	29.63
	10 AM	29.62
	11 AM	29.62
	12	29.56
	1 PM	29.62
	2 PM	29.50
	3 PM	29.49
	4 PM	29.50
	5 PM	29.50
3-9	7 AM	29.14
	8 AM	29.11
	9 AM	29.11
	10 AM	29.11
	11 AM	29.15
	12	29.15
	1 PM	29.15
	2 PM	29.15
	3 PM	29.25
	4 PM	29.31

13.0 APPENDIX 7

Table 1: Comparison of Control and Treated Fleet Smoke Numbers

		Control 1			*Treated 1	
Throttle	**2311**	**2302**	**2308**	**2315**	**2301**	**2309**
2	5.00	6.00	5.00	5.00	5.00	6.25
4	7.00	7.25	7.00	6.00	6.00	8.00
6	8.50	8.75	8.00	7.50	7.75	9.50+
8	8.50	8.25	8.25	7.50	8.75	9.25+
AVERAGE:	**7.25**	**7.56**	**7.06**	**6.50**	**6.87**	**8.25**

		Control 2			**Treated 2	
Throttle	**2311**	**2302**	**2308**	**2315**	**2301**	**2309**
2	4.50	5.50	5.00	4.00	3.00	5.00
4	7.00	7.25	6.75	5.50	5.25	6.50
6	8.25	8.00	8.00	7.50	7.50	8.00
8	8.50	7.50	7.50	5.50	6.50	6.25
AVERAGE:	**7.06**	**7.06**	**6.81**	**5.62**	**5.56**	6.44
% Change:	-2.6	-6.6	-3.5	-13.5	-19.1	-22.0

* Treated fleet without FPC-1

** Treated fleet after one month of FPC-1 use

\+ The smokespot number was off the scale (0 to 9), therefore, the smokespot is assigned a smoke number of 9.5. The smoke density could be greater than a 9.5.

14.0 APPENDIX 8

Table 2: Percent Change over Baseline Fuel Consumption for the Control Fleet

Unit No.	Notch 2	Notch 4	Notch 6	Notch 8
2311	-1.43%	+1.68	-0.95	+0.53
2302	-0.01	-1.16	+1.01	+1.01
2308	-2.68	+1.06	+2.89	+1.83
AVERAGE:	**-1.37**	**+0.53**	**+0.98**	**+1.12**

AVE. ALL TESTS: +0.31%

Table 3: Percent Change over Baseline Fuel Consumption for the Treated Fleet

Unit No.	Notch 2	Notch 4	Notch 6	Notch 8
2315	-8.71%	-3.11	na	-4.31
2301	-4.03	-3.62	-4.02	-4.61
2309	-6.23	-0.72	-1.78	-2.41
AVERAGE:	**-6.32**	**-2.48**	**-2.90**	**-3.78**

ALL TESTS: -3.96%