Coal-Fueled High-Speed Diesel Engine Development

**Final Report
September 28, 1990 - November 30, 1993**

**R. M. Kakwani
R. E. Winsor
T. W. Ryan, III
J. A. Schwalb
S. Wahiduzzaman
R. P. Wilson, Jr.**

September 1993

Work Performed Under Contract No.: DE-AC21-90MC27222

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Detroit Diesel Corporation
Detroit, Michigan

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EXECUTIVE SUMMARY

The goal of this program (DOE/METC contract number DE-AC21-MC27222) was to study the feasibility of operating a Detroit Diesel Series 149 engine at high speeds using a Coal-Water-Slurry (CWS) fuel. The CWS-fueled 149 engine is proposed for the mine-haul off-highway truck and work boat marine markets. Economic analysis studies indicate that, for these markets, the use of CWS fuel could have sufficient operating cost savings, depending upon the future diesel fuel price, emission control system capital and operating costs, and maintenance and overhaul costs. A major portion of the maintenance costs is expected to be due to lower life and higher cost of the CWS injectors.

Injection and combustion systems were specially designed for CWS, and were installed in one cylinder of a Detroit Diesel 8V-149TI engine for testing. The objective was to achieve engine operation for sustained periods at speeds up to 1,900 rpm with reasonable fuel economy and coal burnout rate. A computer simulation predicted autoignition of coal fuel at 1,900 rpm would require an average droplet size of 18 microns and 19:1 compression ratio, so the injection system, and piston were designed accordingly. The injection system was capable of supplying the required volume of CWS/injection with a duration of approximately 25 crank angle degrees and peak pressures on the order of 100 MPa. In addition to the high compression ratio, the combustion system also utilized hot residual gases in the cylinder, warm inlet air admission and ceramic insulated engine components to enhance combustion.

Autoignition of CWS fuel was achieved at 1900 rpm, at loads ranging from 20 - 80 percent of the rated load of diesel-fuel powered cylinders. Limited emissions data indicates coal burnout rates in excess of 99 percent. NO_x levels were significantly lower, while unburned hydrocarbon levels were higher for the CWS fueled cylinder than for corresponding diesel-fuel powered cylinders. The program also investigated effects of spray-tip configuration (number and size of orifices), but found no significant improvements. The affect of tip material on spray-tip orifice wear rate was investigated, but for all the materials tested in this program, the wear rate was still unacceptably high.

INTRODUCTION

During the past several years, DOE/METC has sponsored many programs to develop coal-fueled diesel engines. These efforts have made significant progress in developing technology for low and medium speed diesel engines capable of operating on these fuels. Two major programs were conducted by GE and A.D. Little/Cooper-Bessemer to commercialize coal-fueled diesel engines for locomotive and cogeneration applications, respectively. These programs solved many of the problems associated with burning coal in a diesel engine and demonstrated single-cylinder and multi-cylinder engine operation on CWS. Excellent progress was made in the areas of CWS injection and combustion at engine speeds of 1050 rpm (GE) and 300 to 450 rpm (Cooper-Bessemer). Also, the economic analysis indicates that coal-fueled engines can provide good return on investment assuming reasonable diesel fuel costs. Some of the problems associated with wear of the high pressure CWS injector nozzle holes, cylinder liners and piston rings were pursued by GE, A. D. Little and other R&D companies (Webb et al., 1990).

DOE/METC has also funded research programs to investigate combustion of coal powder and CWS in low heat rejection (adiabatic) engines. The objective of these programs was to enhance coal combustion by the higher in-cylinder gas temperatures achieved in these engines. In an uncooled single-cylinder prechamber diesel engine, combustion of fumigated coal powder fuel and CWS injected into the prechamber was achieved at speeds up to 1,800 rpm (Kakwani et al., 1989 and 1990).

Concurrent with the work described above, Detroit Diesel Corporation (DDC) began developing the Series 149 engine for operation on CWS fuel at high speeds for the mine-haul off-highway truck and towboat marine markets. The 149 diesel engine has a major share of these markets, and a coal-fueled version of the engine would have the following economic and technical merits.

- Series 149 engines use a large amount of fuel. For mine-haul off-highway trucks (170 tons), 16V-149TI engines are used at 1,800 to 2,200 hp. The average load factor for a typical mine-haul truck is about 35%, and it operates 5,000 to 7,000 hours per year. In the case of a work boat engine, the load factor is greater than 50% and there are 5000 to 8000 operating hours per year. Because of this, even a small cost advantage of coal over diesel fuel could translate into major cost savings.
- An increase in the engine cost due to the coal fuel injection system, wear-resistant components, and the emission control system could be tolerable on a Series 149 engine because it would likely be small relative to the total cost of the engine. In contrast, the cost increase of a smaller on-highway coal-fueled engine would be unacceptable when compared to the cost of the basic diesel engine.
- The 149 engine currently has a large market share of the off-highway truck, industrial and marine applications. Therefore, a coal-fueled version of the engine would have many possible applications.
- A large off-highway engine, like the Series 149 engine, would be better suited to accept the additional space and weight requirements of the emission control system posed by the use of coal fuels. Also, emission regulations for off-highway are not expected to be as stringent as those for on-highway engines because off-highway trucks, industrial engines and marine vessels normally operate in remote areas away from population centers.

All of the CWS-fueled engine programs have had to address the problems of reliability of the fuel injection system, coal fuel ignition and combustion, and wear. These issues were made even more severe in the case of the 149 engine because of its relatively high engine speed, allowing less time for ignition and combustion, and exacerbating the wear problems.

PROGRAM OBJECTIVES AND DESCRIPTION

The objectives of this program were to study combustion feasibility by running Series 149 engine tests at high speeds with a fuel injection and combustion system designed for CWS. The following criteria were used to judge feasibility:

- Engine operation for sustained periods over the load range at speeds up to 1,900 rpm. The 149 engine for mine-haul trucks has a rated speed of 1,900 rpm.
- Reasonable fuel economy and coal burnout rate
- Reasonable cost of the engine design concept and CWS fuel compared to future oil prices.

Detroit Diesel Corporation (DDC) was the main contractor with Diesel Technology Corporation (DTC), Southwest Research Institute (SwRI), Ricardo North America and A. D. Little, Inc. (ADL) as subcontractors. The overall work plan involved the following four tasks.

- Task 1—Program Plan and Technology Review
- Task 2—Conceptual Design and Market Assessment

- Task 3—Component Design, Fabrication and Bench Tests
- Task 4—Full-Scale Single-Cylinder Diesel Engine Modification and Test

In general DDC oversaw the entire project, assisted in the design of injection system components, designed and fabricated combustion system components, and built the 8V-149TI engine used in testing. ADL performed an economic analysis and market assessment for the 149 coal-fueled engine and Ricardo performed cycle simulations of the engine concepts which were used in the design of injection system and combustion system components. DTC and SwRI were involved with the design and fabrication of the CWS injection system. Bench tests of the injection system were conducted at SwRI. Following bench tests, the engine was installed in a test cell at SwRI, and the injection system was installed into one cylinder of the engine. Engine tests were then performed using the CWS fuel over a range of timings, loads and intake air conditions.

ECONOMIC ANALYSIS AND MARKET ASSESSMENT

Objectives and Approach

The objective of this task was to identify the market potential and economic feasibility of the future coal-fueled, high-speed diesel engine. The results of this task were expected to determine what specific heavy duty engine and application(s) are most attractive for coal fuel, and also define basic economic factors for the engine to be competitive, such as:

- Source coal location and price
- Coal cleaning cost, given assumed CWS specifications
- Engine parts cost increase to permit operation with coal fuel
- Load factor (equivalent full load hours per year)
- Maintenance and operating costs
- Emission control system capital and operating costs and size
- Diesel fuel costs at which the coal-fueled engine is cost competitive

Several applications for heavy duty diesels in the 300-2,500 hp output class were surveyed, including off-highway mine-haul trucks, construction and industrial, marine and generator set applications. A set of "attractiveness criteria" for coal fuel operation was developed to screen the full range of engine applications. This preliminary screening resulted in two applications which appeared particularly well suited for coal fuel:

- Mine-haul trucks equipped with a 16V-149TI diesel engine of 1,600 to 2,200 hp. These 170-240 ton trucks operate in overburden and open pit mines including coal, iron ore and copper.
- Barge, tug and work boat engines in the marine inland water-way sector. Most of the existing 4,000 engines are naturally aspirated with 800 to 2,000 hp and have relatively long service lives.

Next, more detailed information for these two selected market applications was prepared to better assess their feasibility and relative merit. This information included market share, duty cycle for engine operation, historical annual sales, emission control requirements, and specific geographical locations for the engines now in use (which allowed for selection of suitable coal mines nearby). A detailed economic

feasibility analysis was then performed using a spreadsheet model for life-cycle engine and fuel costs. Parametric studies were performed to explore the relative impact of various parameters such as:

- Load factor
- Clean coal fuel cost relative to diesel fuel
- Engine efficiency
- CWS injector nozzle life
- Financing rate

Selection of Engine Applications

Candidate 300-2,500 hp Engine Applications

Heavy-duty diesel engines in the 1,700-2,100 rpm rated speed class are widely recognized for their use in the on-highway trucks and buses, where they account for approximately 6% of U.S. fuel oil usage. However, there are other applications for heavy-duty diesels in which Detroit Diesel enjoys a significant market share. These applications are less widely known, but may be more suitable for adaptation to coal-water slurry fuel, such as:

- Off-highway, including mine haul trucks
- Marine propulsion, including inland waterway vessels
- Generator sets and industrial drives

Selection Criteria for Coal Fuel Feasibility

Previous work on clean coal fuels for reciprocating engines has shown that the emission control requirements and the total annual fuel usage per engine are two factors of primary importance for economic feasibility. Annual fuel usage is critical because the benefit for the engine operator will be the lower cost of coal fuel compared to diesel fuel. In brief, the engine must burn enough coal fuel each year to pay for the extra cost of emission control (which is technically feasible, but relatively expensive on a \$/engine basis). For example, an application with 1,500-2,000 hp engines operating 2,000 to 4,000 full-load equivalent hours/year and moderate emission control requirements will be preferred to a 500-1,000 hp engine application with only 1,500 full-load equivalent hrs/year and stringent emission controls. This is why the highway truck application is not attractive for coal fuel.

Another consideration is that the application must require enough engines operating in a given region to justify a coal-cleaning plant (here the threshold level is about 500,000 hp, or 250 engines in the 2,000 hp class). Preferably, those regions with large concentrations of coal-fueled engines will be in close proximity to "engine-grade" source coals (that is, coals which can be economically cleaned to about 2% ash or better) (Wilson, 1991).

Also, the future potential displacement of oil by coal must be sufficient to justify the DDC coal engine development, and this implies that the total U.S. installed horsepower must be significant. For example, an engine application with an installed base of 4 million hp in the U.S. will account for 0.1 quad/year (10^{14} Btu/year) of fuel usage, assuming 3,000 full-load hours and 8,000 Btu/hp-hr specific energy consumption rate. This is about 3% of total U.S. oil consumption (6% of oil imports) which is quite significant.

Another factor favoring large engines is the cost of special hardware to burn coal fuels. This may include the injection system, wear-resistant parts for the injector tips, the piston rings and liners, the turbocharger, and the exhaust valves. This special hardware is expected to cost \$30,000 to \$100,000 per engine (dependent on engine size), which is tolerable for 1,500-2,000 hp engines but exceeds the engine cost itself for engines of less than 500 hp.

Past development work on coal-fueled diesel engines has shown that these engines favor steady operation with minimum load and speed changes. Cold starts should also be kept to a minimum. Therefore, applications are favored which offer a large amount of engine operating time at steady load and speed, such as the marine propulsion application.

Screening of Engine Applications

Table 1 lists the evaluation criteria discussed above, and shows how four candidate diesel engine applications were evaluated. A simple numerical rating system was used, and the outcome was so definitive that it was unnecessary to develop a more sophisticated evaluation method. The marine and mine-haul applications received scores of +14 and +12, respectively (far above the other two candidates). The generator set industrial engines and bus/truck applications did not score well in economic feasibility, largely because of the relatively small engine size, low fuel usage per engine and stringent emission control requirements. In many U.S. locations, there is pressure to replace industrial drives with electric motors because of emission regulations. The bus/truck application, although attractive for its large national fuel usage, also suffers from a non-steady duty cycle and the need to have a clean coal fuel infrastructure throughout the highway system.

As a result of this screening, the inland waterway tow boat and mine haul truck engine applications were selected as attractive for adaptation to coal slurry fuel. These applications are examined in more detail in the following sections.

Mine Haul Truck Application

Background

Mine haul trucks in the 170-240 ton class are the largest trucks produced and are about 20 ft. tall, 40-50 ft. long, with tires standing over 10 ft. tall. Empty, the vehicle weighs up to 350,000 lbs. Typically, mine haul trucks are used for open-pit mines to transport overburden and coal (or ore) out of the mine pit. The trucks cost about \$1.5 million, with the engine itself accounting for about 15% of the total cost.

Both electric drive models (diesel engines powering an alternator) and mechanical drive models (electronic transmission) are currently offered with key truck manufacturers including Marathon LeTourneau, WISEDA, VME-Americas, Unit Rig, and Dresser-Komatsu (Haulpak). The mine haul truck is suited for the coal fuel operation because 1,500-2,200 hp engines are used for 16 to 24 hours per day with a high load duty cycle. DDC Series 149 engines enjoy a significant market share in the U.S. (approximately 50%), and also are exported to mines in South America, Australia, South Africa, China, and India. This opens up the possibility of export sales of the U.S. clean coal technology and coal-fueled diesel engines.

The mine haul truck market in the U.S. is in the range of 600 to 800 trucks per year, with 40% going to coal surface mines in ND, TX, WY, KY, and WV; 25% going to iron ore mines mainly in Minnesota; and 35% going to copper mines in AZ, NM, NV, and UT. Currently, there are an estimated

Table 1. Evaluation Criteria for DDC Coal Engine Application

	Relative Ability to Accommodate Clean Coal Slurry			
	Marine	Gen Set	Mine Haul	Bus/Truck
A. Economics				
Annual fuel usage per engine	+2	+2	+2	-1
Sufficient engine population for CWS plant	+1	0	+1	+2
Total number of engines in use	+1	0	+1	+2
Cost of emission control to satisfy (future) requirements	+1	-1	+1	-2
Cost of special engine hardware to burn coal	+1	-1	+1	-1
Proximity to low-cost source coals	+2	0	+1	-1
Subtotal	8	0	7	-2
B. Technical Feasibility				
Duty cycle-load changes and turndown; number and frequency of coal stats	+2	+2	+1	-2
Impact of unscheduled downtime	-2	-1	-2	-2
Subtotal	0	+1	-1	-4
C. Logistics and System Design Constraints				
Fuel processing facility and local bunkering facility	+1	+2	+2	-1
Space available next to engine for emissions control equipment	+2	0	+1	-2
Accommodation of other on-vehicle subsystems				
-- larger CWS fuel tank/separate DF2 loop for pilot/load fuel	+2	+1	+1	-1
-- injection system changeout/frequent maintenance	+1	-1	+2	+1
Subtotal	+6	+2	+6	-3
Total Score	+14	+3	+12	-9
Ratings: +2 No problem; or superior fit with CWS +1 Probably acceptable, but needs engineering 0 Unknown; to be determine -1 Problem identified -2 Significant problem identified which may be insurmountable				

6,000-8,000 trucks in service with an average engine life of about 50,000 operating hours (typical useful engine life is estimated to be 10 years at 5,000 hours per year).

The larger mines operate a fleet of 15 to 30 active large trucks for 24 hours per day, with a diesel fuel consumption of 2 to 5 million gallons per year. Fuel is typically 15-20% of the operating cost per ton for a 100,000 ton/day mine. The large fuel oil budget of each major mine operator means that penetration of this market segment by coal engines can be accomplished readily, provided the cost savings with the use of coal-fueled engines are demonstrated.

The overall fuel usage in the U.S. by this engine application can be estimated as follows. If 2,000 active trucks are assumed to use 25 gallons per hour of diesel fuel for 4,000 hours per year, the total estimate is 200 million gallons per year (0.03 quad). Alternatively, if the total annual tonnage in surface mines (coal, ore, and overburden) is 1,000 million tons, and an average fuel use of 0.15 gallons per ton is assumed, one obtains 150 million gallons per year (0.02 quad). These estimates are reasonably consistent and give the total potential national impact of coal fuel substitution for the mine haul truck market.

Mine Locations and Coal Slurry Logistics

Three major types of surface mines use the mine haul trucks, as described below:

- Coal mines (Wyoming, North Dakota, Montana, and Texas),
- Iron ore mines (Minnesota), and
- Copper mines (Arizona, Utah, Nevada, and New Mexico).

For the coal mines in the Powder River Basin (Wyoming, North Dakota and Montana), it is clear that the preferred source coal for a clean coal slurry powered truck fleet would be in that same region. It has been demonstrated that several coals in this region are indeed cleanable to engine grade quality. The AMAX/ADL coal cleaning plant model Wilson (1991) suggests a typical clean coal slurry price produced near the mine site in the Powder River Basin would be \$2.92/MMBtu in 1991 dollars.

For the copper mines in Arizona and neighboring states, the western source coals are also most convenient, but there would be a transportation cost to the slurry plant, because this plant must be located 20-50 miles from the mine haul truck fleets. For example, assuming a Salt Lake City slurry plant location, the AMAX/ADL coal cleaning plant model suggests a slurry price of \$3.55/MMBtu, including \$0.55/MMBtu for transportation.

Schematic Design of Coal Engine System for Mine Haul Truck

The 149 coal engine system would incorporate the same package as for the 149 diesel engine with the exception of special coal tolerant injection system and in-cylinder components. Also, this will include two new modules:

- Coal slurry fuel tank (about 1,200 gallons capacity), and
- Emission control system.

The coal slurry fuel tank will replace one of the two 300-600 gallon diesel fuel tanks currently found on the truck underbody. The emission control system is expected to be located beside the cab under the overhang, so as to minimize interference to the vision of the operator. Figure 1 illustrates the schematic design of the emission control system components.

Inland Waterway Towboat Application

Inland waterway transport is a major U.S. mode of freight traffic consisting mainly of barges pushed or pulled by diesel powered tugs or towboats. Each boat typically moves 10 to 16 barges with the engine operating close to full load. Figure 2 shows a typical inland waterway towboat in operation. These engines operate on a continuous basis for about 5,000-6,000 hours per year and are rated more conservatively than the mine haul truck engines. This is potentially an excellent application for coal fuel because of steady operation with a high load factor.

Figure 1. Emission Control Device for Coal-Fired Diesel Mine-Haul Truck (2,000 Hp)

Figure 2. 1,800 hp Viking Class Towboat

Table 2. Inland Waterway Towboat Engine Database Results

Engine Model	Typical Vessel (hp)	Number of Vessels	Total Horsepower	Retrofit Potential for DDC 149 Coal Engine
DDC Model 92	600 to 1,200	151	162,000	Possible with 8V-149
DDC Model 149	1,350 or 1,800	190	287,000	Excellent
EMD Model 567	3,000 (average)	160	418,000	Good
Miscell GM	2,000 (average)	42	79,000	Good
DDC Model V-71	500-1,000	1,340	851,000	Poor
6-110	Approx 400	75	27,000	Poor
<i>EMD Model 645</i>				
12 cyl.	2,800 or 4,300	124	444,000	Excellent
16 cyl.	3,400 to 9,000	244	1,210,000	Excellent
20 cyl.	7,000 to 10,500	32	253,000	Poor
8 cyl.	1,800 or 3,000	287	9,000	Good
<i>Other manufacturers</i>				
Cummins, Caterpillar, Alco	varies: 500-4,000	1,303	1,646,000	Good for certain engines
Totals		3,690	4,454,000	

Existing Towboat Engines—Population and Fuel Usage

Based on data provided by Waterways Journal, Arthur D. Little, Inc. compiled an engine database of 3,700 work boats active on inland waterways in the U.S. The database shows vessel serial number, engine manufacturer and model, vessel horsepower, and year built. The results are summarized in Table 2. The retrofit potential is noted in the last column, largely based on engine size. It is clear that of the 4.5 million horsepower presently installed, 50-75% of towboat engines have the potential to be replaced by the 149 coal-fueled engines, when developed.

Combining the duty cycle data with the operator fuel use data, implies that active towboat engines operate an average of 3,200 (+/- 300) hours per year. This is about a 40% overall load factor on an annual basis. The average specific fuel consumption over the duty cycle was assumed to be 0.05 gallon/hp-hr in agreement with the operating data. Total U.S. fuel usage for this engine application was estimated at 765 million gallons per year (0.11 quad). This is about three times the estimated fuel usage by the mine haul sector. DOE/EIA statistics (Petroleum Marketing Annual, 1988) show distillate fuel oil vessel bunkering averaged 765 million gallons for 1987 and 1988, distributed as follows:

<u>State</u>	<u>Million gallons</u>
Kentucky	85
Missouri	44
Tennessee	91
Louisiana	460
Mississippi	85

This excludes Florida, Alabama, and Texas, which together account for an additional 500 million gallons per year, much of which is used for coastal and Gulf of Mexico activities.

Towboat Operating Routes and Coal Slurry Logistics

The majority of inland waterway activity is along the Mississippi River and its tributaries, as noted by the fuel usage statistics cited above. Towboats typically carry 20,000 gallons of fuel oil which can allow them to operate up to four weeks without refueling.

Source coals which are readily cleanable are available from mines which are in close proximity to the Mississippi river waterway system (e.g., Kentucky, West Virginia, Virginia, Ohio, Missouri, Pennsylvania, Illinois). The slurry plant serving a towboat fleet can be most logically placed at an existing bunkering terminal, with coal transported at low cost by barge to the slurry plant. This system of coal fuel logistics lends to a relatively low cost engine-grade slurry. For example, if Pittsburgh is selected as a slurry plant site and a 1-2% ash specification is assumed, the coal fuel price would be \$3.00/MMBtu, according to the AMAX/ADL coal cleaning model.

Emission Control System for Mine Haul Truck and Towboat Engines

Emission control options were considered and preliminary design sketches prepared as a basis for the economic analysis. The design criteria assumed are presented in Table 3.

For each of the two high-speed engine applications, adequate emission control can most likely be achieved through: in-cylinder NO_x control; coal cleaning and post-combustion SO₂ removal; and a two-component particle removal scheme, such as a cyclone followed by a fabric filter. Since the flyash from coal-fueled diesels operating on highly beneficiated coals contain a large percentage of carbon (e.g., 50-70%), the feasibility of periodic incineration of captured particulate matter must be considered.

Task 2 Topical report (Wilson, 1991) of this program contains the itemized equipment list for the hypothetical coal engine emission system which meets the above specifications. Two configurations are illustrated for comparison; the differences are not great. Estimated costs are given for a 2,000 hp engine (mine haul truck) and a pair of 1,000 hp engines feeding a similar system (towboat). The emission system is estimated to cost \$93,500 to \$111,600 without installation, depending on the application.

Table 3. Emission Control System Design Assumptions

	Performance
SO ₂	50-70% reduction (depending on fuel sulfur)
NO _x	20-40% reduction
Particulate matter	95-99.5% reduction (to meet California off-road standards)
Cost	<\$20/hp-yr
Size of Emission Control Module	<8' x 10' x 10'
Weight	<2 tons
Load range	idle - 100%
Load transients	TBD
Vibration loads	TBD
Change in orientation	9 from horizontal

Engine Spreadsheet Model for Lifecycle Costs

A Lotus 1-2-3 spreadsheet model was developed to analyze the total lifecycle cost of using the 149 coal-fueled engine under various assumptions. The spreadsheet model includes all aspects affecting the cost of owning and operating an engine, including:

- source coal costs including transportation
- capital and operating costs of the slurry plant by coal type and its location
- engine capital costs including installation
- maintenance costs including parts replacement intervals
- emission control costs (capital and operating)

Both coal-fired and oil-fired engines are analyzed in the cost calculation tables. The model takes the user specified input parameters and constants and estimates (1) the engine and emissions capital costs, (2) the engine and emissions operating costs, and (3) the maintenance costs in dollars per year (\$/year) for the oil and coal engines. These costs are totalled and the difference between these values determines the cost savings realized by using the coal engine for a given application and a given scenario.

Engine Efficiency and Fuel Cost

In each of the model runs, the baseline case for the oil-fired engine assumed \$.60/gallon oil costs, which represents typical costs of diesel fuel in 1991. Scenario 1 for the oil-fired engine assumed \$1.10/gallon oil costs, which might be anticipated if oil prices rise, and when the coal engine becomes available. The oil-fired engine efficiency over the duty cycle was arbitrarily set at 34%. A typical average cycle efficiency of the 149 engine over a duty cycle for the mine haul truck or towboat may range from 32% to 37% (based on HHV), depending on the amount of part load and idle operation. It should be noted that engine manufacturers conventionally quote the engine efficiency based on lower heating value (LHV). The 149 engine has a peak efficiency of 40% (LHV), and the operating efficiency over the duty cycle would range from 34 to 38% (LHV).

The Coal Slurry Cost Summary section of the spreadsheet model was used to calculate the itemized costs of the coal, slurry plant operations and slurry plant capital costs. Table 4 presents an example of the slurry costs which are presented in dollars per million BTU higher heating value (\$/MMBTU). The delivered coal price is made up of the cost of the coal at the minemouth and the transportation costs to the slurry plant. The operations and capital costs of the slurry plant (excluding the coal costs) were determined from the data entered in the Slurry Plant Operating and Capital Cost section of the model.

Table 4. Slurry Cost Summary

Description	\$/MMBTU (HHV)
Delivered Coal Price	1.79
Total Opns Cost (excluding coal)	1.21
Capital Recovery	0.46
Total Slurry Cost	3.47

Engine Capital and Operating Costs

The Engine Capital Cost section of the spreadsheet model uses financial statistics, operating statistics, and the capital cost of the components of the engine including the emissions equipment costs and determines an annual capital charge in dollars per year (\$/year). The annual capital charge is converted to a cost per output (\$/kWh) and then apportioned as engine costs and emissions costs in \$/kWh. Tables 5 and 6 display the capital cost information for the coal and diesel engines, respectively.

The Engine Maintenance Cost section in the spreadsheet model uses the maintenance intervals of major components of the engine in hours/cycle and cost per maintenance service for each of the engine components, and the life of the engine to determine the number of maintenance cycles (parts replacement) for each component and the life cost. The total maintenance cost in dollars per engine life is converted into a cost in dollars per kWh. Tables 7 and 8 present an example of the maintenance costs for the coal and diesel engines, respectively.

The total capital and operating costs were calculated for the coal and diesel engines to determine the cost benefit for using coal-fired engines in place of oil-fired engines. Tables 9 and 10 display an example of the engine capital and operating costs on \$/kWh and \$/year basis for the coal and diesel engines, respectively.

Analysis of Economic Feasibility

The spreadsheet model, summarized previously, was used to perform an analysis of the economic feasibility of operating a coal-fueled engine in the two selected applications. More than 50 runs of the model were made, resulting in several plots comparing the cost savings per year generated by using a coal engine in place of an oil-fired engine for different assumed scenarios. In each plot, fuel oil price was the basic independent parameter used on the horizontal axis.

In order to evaluate the two selected applications, representative locations were assumed. Salt Lake was assumed to be a representative Western site for the mine haul truck fleet (Copper mines and surface coal mines are in Arizona, New Mexico, Utah, and Powder River Basin). Pittsburgh was chosen as a typical inland waterway tow boat refueling location—it is one of many cities on the inland waterway. The proximity of these application sites to coal sources was taken into account. The AMAX slurry plant model was run to determine slurry plant and transportation costs. Colowyo coal was used for the Salt Lake site for mine haul trucks, due to its proximity. Blue Gem coal from Kentucky was selected in the model to determine the slurry plant and transportation costs for the Pittsburgh site for refueling tow boats.

The effect of several parameters was studied to determine their effect on the cost savings resulting from using coal engines instead of oil-fired engines for these applications. The parameters modified are as follows:

- Nozzle life—how maintenance costs of critical parts affect savings
- Coal cleaning costs—how slurry fuel costs affect savings
- Interest rates—how the cost of money affects savings
- Diesel fuel use—how the use of diesel fuel for idling affects savings
- Engine efficiency—how a drop in engine efficiency would affect savings

Table 5. Coal-Fueled Engine Capital Cost

Description	Units	Base Case
Financial Statistics		
Cost of Capital	%	12.00%
Recovery/Term	years	20
Operating Statistics		
Power Rating]	Megawatts	1.5
Analysis Period	years	20
Availability	%	90.00%
Load Factor	%	40.00%
Full Load Equiv. Hours	Hrs. Per Year	3154
Power Generated	MWH	95,000
Capital Cost Components		
Lube System		\$8,000
Pistons & Piston Rings		\$21,300
Cylinder Liners		\$8,800
Cylinder Head		\$28,800
Valves		\$9,600
Fuel Pump & Injector		\$16,400
Instruments/Controls		\$15,000
Turbocharger		\$15,300
Cam Shaft & Bearings		\$7,600
Miscellany		\$34,650
Subtotal Critical Parts		\$165,450
Non-Critical Parts		\$123,000
Production Engine Cost		\$288,450
Installation Cost		\$144,225
Installed Engine Cost		\$432,675
Emissions Equipment		\$130,000
Total Capital Outlay		\$562,675
Annual Capital Charge	\$/year	\$75,330
Capital Charge/Output		
Principal Component	\$/kWh	\$0.0059
Cost of Capital		
Total Charge/Output	\$/kWh	\$0.0099
	\$/kWh	\$0.0159
Total Capital Cost/Output		
Engine	\$/kWh	\$0.0122
Emissions	\$/kWh	\$0.0037

The results of this work for the mine haul truck and inland waterway engines is summarized below.

Mine Haul Truck Application

The model assumed a single 1.5 MW (2,000 hp) engine for a mine-haul truck. Parametric studies were conducted at three load factors, diesel fuel cost from \$0.60 to \$1.10 per gallon, two coal cleaning costs, two CWS injector nozzle lifetimes, and two financing rates. Figures 3 to 5 present results of this study. As one would expect, the load factor and coal cleaning cost have a significant effect on the annual savings. Assuming a coal cleaning cost of \$1.21/MMBtu and an average engine efficiency of 34% over the vehicle operating cycle, a mine-haul truck application in Salt Lake City breaks even at diesel fuel

Table 6. Oil-Fired Diesel Engine Capital Cost

Description	Units	Base Case
Financial Statistics		
Cost of Capital	%	12.00%
Recovery/Term	years	20
Operating Statistics		
Life	Megawatts	1.5
Availability	years	20
Load Factor	%	90.00%
Power Generated	%	40.00%
	MWH	95,000
Capital Cost Components		
Standard Engine Cost		\$22,000
% Cost of Critical Parts		44.00%
Value of Critical Parts		\$96,800
Adj. For Critical Parts		100.00%
Adj Cost-Critical Parts		\$96,800
Production Engine Cost		\$220,000
Instruments Cost		\$110,000
Total Capital Outlay		\$330,000
Annual Capital Charge		\$44,180
Capital Charge/Output		
Principal Component	\$/kWh	\$0.0035
Cost of Capital	\$/kWh	\$0.0058
Total Charge/Output	\$/kWh	\$0.0093

price of \$1.00 per gallon at a load factor of 25% (see Figure 3). As the load factor increases, the break even cost of diesel fuel is reduced to \$0.95 per gallon. As expected, a reduction in coal cleaning costs increases the annual savings.

The CWS injector nozzle life was varied in the model to give an indication of the relative effect of maintenance costs of a high wear component of the coal-fueled engine. Figure 4 summarizes the yearly savings for the mine haul truck application for two nozzle life values of 500 hours and 1,000 hours. It was seen that a doubling of the nozzle life has a smaller cost savings than reducing the coal cleaning cost in half. For a load factor of 25%, the break even diesel fuel cost is reduced from \$.98/gallon to \$.95/gallon by doubling the nozzle life.

The financing rate was varied to study the effect of the cost of money on the annual cost savings generated by using a coal engine in place of an oil-fired engine for a mine haul truck application. For a load factor of 25% and a coal engine efficiency of 34%, the diesel fuel cost break even point is \$.95/gallon for an interest rate of 12% as compared to \$1.06/gal for an interest rate of 16%. Figure 6 presents the annual cost savings for the mine haul truck fleet in Salt Lake City for interest rates varying from 12% to 16%.

For the above parametric runs, the engine model assumed that the mine haul truck coal engine was fueled with 100% coal at all operating conditions. Since the mine haul truck engine operates at idle speed and load during the downhill and loading periods, it may be necessary to use diesel fuel in addition to the coal fuel at these low loads. In order to account for this possibility, the spreadsheet

Table 7. Coal Engine Maintenance Cost

Description	Units	Base Case
Maintenance Intervals		
Oil/Fuel/Air Filters	Hrs/Cycle	250
Injector Replacement	Hrs/Cycle	500
Top End Overhaul	Hrs/Cycle	8,000
Major Overhaul	Hrs/Cycle	20,000
Block Overhaul	Hrs/Cycle	40,000
Cost Per Servicing		
Oil/Fuel/Air Filter	\$	\$300
Injector Replacement	\$	\$4,000
Top End Overhaul	\$	\$20,000
Major Overhaul	\$	\$40,000
Block Overhaul	\$	\$80,000
Servicing Thru 1st Rebuild		
Oil/Fuel/Air Filter	# of Cycles	160
Injector Replacement	# of Cycles	80
Top End Overhaul	# of Cycles	5
Major Overhaul	# of Cycles	2
Block Overhaul	# of Cycles	1
Cost Thru 1st Rebuild		
Oil/Fuel/Air Filter	\$	\$48,000
Injector Replacement	\$	\$320,000
Top End Overhaul	\$	\$100,000
Major Overhaul	\$	\$80,000
Block Overhaul	\$	\$80,000
Total Thru #1 Bottom End		\$628,000
Allocated Maintenance %		
Oil/Fuel/Air Filter	%	7.64%
Injector Replacement	%	50.96%
Top End Overhaul	%	15.92%
Major Overhaul	%	12.74%
Block Overhaul	%	12.74%
Life Service Cycles		
Oil/Fuel Air Filter	# of Cycles	252
Injector Replacement	# of Cycles	126
Top End Overhaul	# of Cycles	7
Major Overhaul	# of Cycles	3
Block Overhaul	# of Cycles	1
120 Year Cost		
Oil/Fuel/Air Filter	\$/Life	\$75,600
Injector Replacement	\$/Life	\$504,000
Top End Overhaul	\$/Life	\$140,000
Major Overhaul	\$/Life	\$120,000
Block Overhaul	\$/Life	\$80.00
Total Maintenance Cost	\$/Life \$/kWh	\$919,600 \$0.0097

Table 8. Oil-Fired Engine Maintenance Cost

Description	Units	Base Case
Maintenance Intervals		
Oil/Fuel/Air Filter	Hrs/Cycle	250
Injector Replacement	Hrs/Cycle	5,000
Top End Overhaul	Hrs/Cycle	11,00
Major Overhaul	Hrs/Cycle	22,00
Block Overhaul	Hrs/Cycle	60,000
Cost Per Servicing		
Oil/Fuel/Air Filte	\$	\$350
Injector Replacement	\$	\$6,500
Top End Overhaul	\$	\$23,000
Major Overhaul	\$	\$45,000
Block Overhaul	\$	\$70,000
Servicing Thru 1st Rebuild		
Oil/Fuel/Air Filter	# of Cycles	240
Injector Replacement	# of Cycles	12
Top End Overhaul	# of Cycles	6
Major Overhaul	# of Cycles	3
Block Overhaul	# of Cycles	1
Cost Thru 1st Rebuild		
Oil/Fuel/Air Filter	\$	\$84,000
Injector Replacement	\$	\$78,000
Top End Overhaul	\$	\$138,000
Major Overhaul	\$	\$135,000
Block Overhaul	\$	\$70,000
Total Thru #1 Bottom End	\$	\$505,000
Allocated Maintenance %		
Oil/Fuel/Air Filter	%	16.63%
Injector Replacement	%	15.45%
Top End Overhaul	%	27.33%
Major Overhaul	%	26.73%
Block Overhaul	%	13.86%
Life Service Cycles		
Oil/Fuel Air Filter	# of Cycles	252
Injector Replacement	# of Cycles	12
Top End Overhaul	# of Cycles	5
Major Overhaul	# of Cycles	2
Block Overhaul	# of Cycles	1
]20 Year Cost		
Oil/Fuel/Air Filter	\$/Life	\$88,200
Injector Replacement	\$/Life	\$78,000
Top End Overhaul	\$/Life	\$115,000
Major Overhaul	\$/Life	\$90,000
Block Overhaul	\$/Life	\$70.00
Total Maintenance Cost	\$/Life	\$441,200
	\$/kWh	\$0.0046

Table 9. Coal Engine Capital and Operating Cost

Description	S/kWh	\$/Year
Operating (Excl Emissions)		
Fuel	\$0.0374	\$177,858
Maintenance	\$0.0097	\$45,980
Total Operating	\$0.0471	\$223,838
Capital (Excl Emissions)		
Emissions	\$0.0122	\$57,926
Operating	\$0.010	\$47,500
Capital	\$0.003	\$17,404
Total Emissions	\$0.0137	\$64,904
Total Cost	\$0.0730	\$346,668

Table 10. Oil-Fired Engine Capital and Operating Cost

Description	\$/kWh	\$/Year
Engine Capital	\$0.0093	\$44,180
Emissions Capital	\$0.0010	\$4,686
Engine Maintenance	\$0.0046	\$22,060
Fuel	\$0.0421	\$200,109
Total Cost	\$0.0571	\$271,035

Figure 3. Mine Haul Truck Coal Engine Cost Savings: Coal Cleaning Cost/Load Factor Effects

Figure 4. Mine Haul Truck Coal Engine Cost Savings: Nozzle Life & Load Factor Effects

Figure 5. Mine Haul Truck Coal Engine Cost Savings: Interest Rate/Load Factor Effects

model was run to calculate the effect of using 5%, 10% and 20% diesel fuel. These runs were made assuming the baseline values for all other parameters and the location of the mine haul truck to be in Salt Lake City. Figure 6 summarizes the effect of diesel fuel use on the annual savings for coal engine efficiency of 34% and a load factor of 25% for the mine haul truck. The coal engine cost savings break even point ranges from \$1.03/gallon at 5% diesel fuel use to \$1.09/gallon at 20% diesel fuel use.

Inland Waterway Tow Boat Application

The model for a tow boat with two 1,000 hp engines shows more annual cost savings than the mine-haul truck application, largely because of higher load factors. Pittsburgh was chosen as the refueling site for the coal-fueled tow boat. Figure 7 shows the effect of load factor and coal cleaning costs for this application. At \$1.21/MMBtu coal cleaning cost and 34% engine efficiency, the break even diesel fuel cost was \$0.82/gallon at a load factor of 40%. As the load factor increases from 40% to 50%, the diesel fuel cost break even point reduces to \$.79/gallon. This is quite significant because diesel fuel prices increased to this level in recent years on an intermittent basis. A reduction in the coal cleaning cost from \$1.21/MMBtu to \$.61/MMBtu at a load factor of 40% reduces the diesel fuel cost break even point from \$.82/gallon to \$.74/gallon for a coal engine efficiency of 34%.

Figure 8 presents the annual savings caused by doubling the injector nozzle life from 500 to 1,000 hours for the coal engine application. It can be seen that a doubling of the nozzle life has a smaller cost savings than reducing the coal cleaning in half. For current nozzle life of 500 hours and a coal engine efficiency of 34%, the break even diesel fuel cost ranges from \$.80/gallon for a load factor of 50% to \$.86/gal for a load factor of 30%.

Figure 6. Mine Haul Truck Coal Engine Cost Savings: Diesel Fuel Use Effects

Figure 7. Tow Boat Coal Engine Cost Savings: Coal Cleaning Cost/Load Factor Effects

Figure 8. Tow Boat Coal Engine Cost Savings: Nozzle Life & Load

Figure 9 shows the effect of varying the financing rate from 12% to 16% on the annual cost savings generated by using a coal engine in place of an oil-fired engine. For a load factor of 50%, the diesel fuel cost break even point increased from \$.89/gallon at 12% interest rate to \$.93/gallon at 16% interest rate.

Figure 10 summarizes the effect of diesel fuel use on the annual savings for coal engine efficiency of 34% and a load factor of 40% for the inland tow boat application. The coal engine cost savings break even point ranges from \$.84/gallon at 5% diesel fuel use to \$.89/gallon at 20% diesel fuel use.

ENGINE MODELING

In order to identify problems with the CWS ignition and combustion at high engine speeds and assess the effectiveness of possible design solutions, a coal combustion model developed at Ricardo North America was used to simulate the 149 diesel engine (Wahiduzzaman et al., 1990). The model was calibrated for the 149 two-stroke engine by performing a simulation of the diesel-fueled engine at the 1900 rpm, (125 bhp/cylinder) operating condition for which engine test results and cylinder pressure data was available. A comparison of the heat release data obtained on a diesel-fueled cylinder and the model are contained in Figure 11. The curves indicated reasonable agreement. The predicted brake power was within 3% of the measured value.

The coal combustion model combines the unique heat and mass transport and chemical kinetic processes of CWS combustion with the normal in-cylinder processes of a diesel engine. It includes a two-stage evaporation submodel for drying of the CWS droplet, a global kinetic submodel describing devolatilization, and a char combustion submodel describing surface gasification by oxygen, carbon

Figure 9. Tow Boat Coal Engine Cost Savings: Interest Rate/Load Factor Effects

Figure 10. Tow Boat Coal Engine Cost Savings: Diesel Fuel Use Effects

Figure 11. Comparison of Heat Release Rate from Predicted and Measured Cylinder Pressure Data

dioxide and water vapor. The combustion volume is divided into multiple zones, whose thermochemistry is determined by in-situ equilibrium calculations. This provides accurate boundary conditions for the CWS droplet combustion submodels and gas phase heat release. A CWS fuel jet development, entrainment and mixing submodel is used to calculate the mass of entrained air in each of these zones. For diesel pilot assist, a separate combustion model was incorporated such that pilot fuel combustion could influence the CWS ignition and combustion processes.

One of the challenges of fueling a high-speed diesel engine with CWS is the time available for ignition and combustion. Since the CWS fuel is inherently difficult to ignite, attention was initially focussed on different ignition concepts. Among the ignition aids and options evaluated were: autoignition, glow plug assist, diesel pilot assist, increased in-cylinder temperature through exhaust residuals, preheating of CWS fuel, increased compression ratio and smaller droplet sizes and preheated inlet air.

A set of operating points for a 16V-149 diesel fueled engine for a typical mine-haul truck were simulated which spanned the range from 100% to 25% load at the rated speed of 1900 rpm and an idling load at 700 rpm speed. For simulations performed for autoignition studies, the predicted coal burnout was unsatisfactory at low loads, or when the droplets were large. In order to improve the burnout fraction, simulations were performed with 5 to 10% of the total fuel energy provided by diesel pilot fuel. This was seen to improve CWS ignition and combustion significantly and higher burnout rates were predicted.

Parametric studies were then carried out to determine whether burnout rates could be improved by modifying compression ratio, droplet size, injection timing, swirl, cylinder surface insulation, injector orifice spray angle and size and fuel temperature. The results of these studies with autoignition are discussed below.

Effect of Compression Ratio

The simulation results show that autoignition of CWS can be achieved at 1,900 rpm if the average droplet size is less than 20 microns. However, the model predicted a poor burnout for CWS at low compression ratios despite an elevated fuel temperature. Figure 12 shows the effect of compression ratio on the coal burnout at 1,900 rpm, full load operating point with a Sauter mean diameter (SMD) of 16-18 microns. These results indicate that a compression ratio of 19 is necessary to achieve satisfactory burnout. At compression ratios higher than 19, excessive peak cylinder pressures were predicted. The simulation also predicted that a compression ratio higher than 20 may be necessary to autoignite CWS fuel at lower loads. However, a high compression ratio for the 149 engine may necessitate derating of the full load power.

Effect of Injection Timing and Droplet Size

The simulation predicted higher burnout rates for smaller droplets (<20 microns) and advanced injection timings of 30-35 deg before top dead center. Figures 13 and 14 present the effect of droplet size and injection timing at 1,900 rpm, 100% and 50% load, respectively. An average droplet size in the range of 16 to 18 microns (small droplets) and 27 to 31 microns (large droplets) were used for these cases. In addition, a higher compression ratio of 23 was used for the large droplets compared to 19 for the small droplets. For the large droplet size, the burnout was predicted to be extremely poor and net positive work could not be achieved for any of the operating cases. On the other hand, for the simulations using small CWS droplets, with the exception of the idling case, autoignition is predicted and a significant amount of CWS is consumed and, consequently, net positive work is obtained. It should be noted here that simulation results are obtained using fixed air box and exhaust conditions. However,

Figure 12. Effect of Compression Ratio: Autoignition
at 1,900 rpm, 100% Load

Figure 13. Effect of CWS Injection Timing & Droplet
Size: Autoignition at 1,900 rpm, 100% Load

Figure 14. Effect of CWS Injection Timing & Droplet Size: Autolignition at 1,900 rpm, 50% Load

the exhaust condition varied significantly for the different CWS injection timings. For example, for full load and small droplet size the average exhaust gas temperatures are 653 K, 672 K, 739 K and 732 K for injection timings of 23, 25, 35, 40 degree BTDC, respectively. Incidentally, these temperatures are lower than the typical values (850 K) for a diesel fueled engine at the same load. Hence, it is unlikely that the existing air system will deliver the same intake boost when the engine is fueled with CWS, so a revised turbocharger match will be required.

Uniform Versus Multiple Droplet Sizes

In all the simulations reported previously, uniform droplet sizes were assumed within a zone. It was envisioned that if smaller particles exist in a zone, the ignitability of the rest of the CWS fuel in that zone will be significantly improved. In order to address this issue, it was decided to explore the effect of droplet size distribution. However, the model currently does not accommodate multiple droplet sizes within a zone. An alternative approach involved the use of a large number of zones and varying the droplet size between contiguous zones. It was decided that for each simulation three sizes of droplets (small, medium and large) would be chosen and any particular zone will receive droplets of a single size only. The frequency of injection of any one of the droplet sizes will depend on the fraction of fuel mass associated with that droplet size. The SMD of the multiple droplet size distribution was set to be equal to the diameter of the medium sized droplet.

Figure 15 presents a comparison of the heat release rates for the uniform and multiple droplet sizes with SMD of 22.1 micron. The multiple size distribution had 9.8% of 17.5 micron small droplets, 80.1% of 22.1 micron medium droplets, and 10% of 30 micron large droplets. The heat release rates indicate earlier ignition and higher peak rate for the multiple droplets with 76.6% burnout as compared to 73.8% for the uniform droplets. Although detailed modeling is required to accurately predict the effect of droplet size distribution, the simulation results indicate that small droplets play a smaller role than seemed likely. The reason for this is that the in-cylinder temperature prior to combustion is highly

Figure 15. Uniform & Multiple Droplet Size Distribution: Autoignition at 1900 rpm, 100% Load

influenced by the evaporation load of the CWS fuel and even if small droplets ignite early, much of this fuel energy is utilized in dehydration of larger droplets.

Effect of In-Cylinder Insulation

In an effort to assess the effect of in-cylinder insulation, simulations were performed with various levels of insulation. For this purpose, the piston top and fire deck surfaces, valve faces and the top 2/3 of the liner surface were assumed to be coated with an insulating material having a thermal conductivity of 0.8 W/m-K. An operating point corresponding to 50% load at 1,900 rpm speed was simulated for coating thickness ranging from 0.5 to 2.5 mm. These results indicated that the burnout and brake power would be improved with increased level of insulation. The average in-cylinder wall temperature increased from 580 K to 743 K with an increase in the insulation thickness from 0.5 to 2.5 mm. This produced favorable in-cylinder conditions for a more complete and earlier combustion of the CWS fuel. This resulted in an increase in the brake thermal efficiency for the insulated 149 CWS-fueled engine. Incidentally, the commercial 149 diesel engine for high power levels already has insulated piston and firedeck surfaces.

Effect of Swirl Level

The effect of intake swirl on CWS combustion was also examined. At an operating condition of 100% load at 1,900 rpm speed with swirl numbers ranging from 1.07 to 2.5, the results predicted that an increase in the swirl decreased the burnout and consequently reduced the power output (see Figure 16). The increase in heat transfer rate due to higher swirl level was predicted to be marginal and, evidently, was not the reason for combustion degradation. Upon closer examination, it was observed that the increased entrainment associated with swirl tends to quench the combustion for the CWS fuel injected during the later part of the injection period. This was a rather surprising result, however, this effect was expected to be less pronounced at higher loads.

Figure 16. Effect of Swirl Level on CWS Burnout and Power Output: Autoignition at 1,900 rpm, 100% Load

Effect of Injector Orifice Spray Angle and Size

Engine modeling was performed to determine the effect of injector parameters on the engine performance. The plume/wall interaction model allows unimpeded growth of the fuel plume until it reaches a bounding wall. The entrainment rate of fresh air into the portion of the plume affected by the wall is based on an empirical scheme. Under this scheme, the entrainment into the affected zones is reduced by a factor proportional to the extent of interaction (degree of wetting). However, the entrainment rate of an affected zone is never allowed to fall below 50% of the rate prescribed by the unmodified model, i.e., the entrainment modification factor is bounded by the values between 0.5 and 1.0. In addition, the model also accounts for the plume/wall heat transfer and its impact on structural and burned zone temperatures. It should be emphasized that the above model is a simple one and mechanisms such as interaction between plumes, self-entrainment (entrainment of a portion of a plume by another portion of the same plume), loss of fuel past the rings and reentrainment of fuel captured by the cylinder walls have not been modeled. It is expected that a change of injection parameters will significantly affect these mechanisms and alter the engine performance, thus underscoring the need for a more accurate model.

In order to assess the effect of injector orifice spray angle and size, the fuel impingement model was also used. For 1,900 rpm, 50% load operating point, the CWS-fueled engine performance improved with an increase in the spray angle from 130 to 160 degrees. For a smaller spray angle, impingement occurs earlier and the fuel plumes remain confined for a longer duration. This results in poor combustion and consequently, lower power output. At higher spray angle, the extent of plume/wall interaction is reduced and hence its effect is much less prominent, as indicated for spray angles of 150 and 160 degrees. At yet higher spray angles, the effect of cylinder liner and plume interaction would be a dominant mechanism affecting the entrainment rate. It is believed that reentrainment of the fuel from the wall jets impacting the cylinder liner is comparatively less efficient due to the presence of crevices. However, this mechanism was not included in the present model and such simulations were not performed at spray angles higher than 160 degrees.

Figure 17. Effect of Injector Orifice Size on CWS Burnout and Ignition Delay: Autoignition at 1,900 rpm, 50% Load

Simulation results of the effect of injector nozzle orifice size on CWS fuel combustion indicated that the engine performance and burnout improves considerably with a reduction in the orifice size. Figure 17 shows that a decrease in the orifice size results in reduced ignition delay and increased burnout. For orifice sizes of 0.3 mm or less, the CWS burnout fraction and power output tend to approach a maximum value. This is due to opposing trends caused by higher injection velocity, which on one hand promotes entrainment and dehydration processes, and on the other hand can cause early plume/wall interaction, which adversely affects the entrainment process. However, practical problems such as orifice clogging and excessive wear may preclude the use of smaller orifice sizes.

Effect of CWS Fuel Temperature

The simulation also assessed the effect of injected CWS fuel temperature on the burnout rates and ignition delay periods. It was observed that CWS burnout was improved by an increase in the fuel temperature from 310 K to 350 K. This gain was achieved because of reduction of the heatup load and time for the injected CWS fuel, which constitutes a significant fraction of the physical ignition delay.

INJECTION SYSTEM DEVELOPMENT

Design of the Injection System

Selection of the Concept

The conceptual design of the injection systems for the 149 coal-fueled high-speed engine considered the following three concepts, seen in Table 11.

- “High” pressure injection (8,000 to 12,000 psi) of CWS to achieve autoignition at high loads and the use of ignition assistance at low loads.

Table 11. DDC 149 Coal-Fueled Engine Injection and Combustion Concepts

	#1A	#1B	#2A	#2B	#3A	#3B	#3C
Concept	HPD	HPG	MPG	MPD	LPD	LPA	LPS
Injector	Conv.	Conv.	Conv.	Conv.	Conv.	Air-Assis	Steam
BOI (DBTC)	25	25	35	35	135	135	135
Inj. Pressure	12,000	12,000	3,000	3,000	500	500	500
Ignition	Pilot	Autoignition*	Autoignition*	Pilot	Pilot	Pilot	Pilot
Other Parts	---	---	Impinging Piston	Impinging Piston	---	Air Compressor	Slurry Heater
Inj. Wear	High	High	Medium	Medium	Low	Low	Low
Problems	Complex	Cold Start	Cold Start	Complex	Knock	Power, Knock	Starting, Knock*
Cold Start Glow Plug for the Cold Start and Warm Up							

- "Medium" pressure injection (3,000 to 4,000 psi) of CWS with impingement on the piston and glow plug or diesel pilot ignition.
- "Low" pressure admission (less than 500 psi, air or steam assist) of CWS after closing of exhaust valves and intake ports with diesel pilot ignition.

Based upon the simulation results that predicted high coal burnout rates at 1,900 rpm speed with autoignition of coal fuel, it was decided to pursue the first concept by injecting CWS into the combustion chamber near top dead center using a high pressure injector.

Design Approach

Previous injection system problems encountered by Ryan et al. (1980, 1982, 1984) consisted primarily of reliability factors associated with sticking of moving parts, packing of coal particles in tight clearances, and plugging of flow passages. Most of these problems were associated with loss of water from the slurry as it passed through the injection system components and came into contact with tight clearances.

The work of Rao et al. (1989), Hsu (1991), and Kimberly (1993) have contributed significantly to the solution of many of these reliability problems. The system design that has evolved as the best approach to the reliability problems involves the use of a free shuttle piston to separate a clean pumping fluid from the slurry (Rao, 1989). In this approach, a standard plunger and barrel assembly is used to meter and pressurize a clean fluid such as diesel fuel. This high pressure fluid acts on one side of a free piston. The slurry is supplied through a check valve to the other side of the free piston where it is pressurized and directed through an injector nozzle. Oil is supplied to both the guide area of the needle valve in the nozzle and to the center of the free shuttle piston. The oil is supplied at pressures exceeding the peak injection pressure so that it acts as both a lubricant and a sealing fluid. This innovation has greatly improved the reliability of the systems and has allowed researchers to develop fairly extensive engine experience with slurries. Sufficient experience has been gained to indicate the next set of problems related to system durability, in particular the durability of the spray holes in the injection nozzle tip. Excellent work by both Flynn et al. (1990) and Mayville et al. (1990) suggests that the spray hole durability problem can be solved by selection of the appropriate material.

The design strategy for the CWS injection system for the 149 engine was to build upon the results of the previous work and to adapt the current technology to the unique requirements of the 149 engine.

The goal was to ultimately develop an electronic unit injector that would fit into the cylinder head in place of the diesel injector. As an intermediate step, a pump-line-nozzle (PLN) injection system was developed as a test bed for new concepts and as a flexible (injection timing control) tool for engine development. In addition, a mechanical unit injector (MUI) for CWS was designed to inject CWS directly (without a check valve) using an oil lubricated plunger.

The unique design considerations for the 149 engine included the fact that the engine runs at speeds from two to five times greater than the medium speed engines used by Hsu et al. (1989) and Rao et al. (1990), respectively. In addition, the system must be able to fill much faster than the other systems because it must inject from four to ten times as often as the other systems due to the fact that the 149 engine operates on a two rather than a four stroke cycle. Another constraint on the system was that the injector nozzle should fit in place of the existing diesel injector so that cylinder head modification would be minimized.

Simulation of the CWS injector was conducted to calculate injection parameters such as pressure, rate and duration, and the camshaft surface (Hertz) stresses for the MUI. The effect of nozzle tip flow area and the CWS properties (density, bulk modulus and viscosity) on the above parameters was investigated. The peak injection pressure was found to be in the range of 69 to 124 MPa (10,000 to 18,000 psi), depending upon the nozzle tip flow area. Figure-18 presents the injection parameters and cam hertz stress for a test run at 1,900 rpm, full load condition. Based upon these simulation results, the number and size of spray holes was selected for the CWS injector and the following specifications were developed:

Figure 18. The CWS Injector Simulation Results at 1,900 rpm, 100% Load Point

CWS Injection amount	= 465 mm ³ /stroke at 1,900 rpm, 100% load
CWS injection pressures	= 69 to 124 MPa (10,000 to 18,000 psi)
Injection duration	= 30 to 35 degrees (maximum)
Beginning of injection	= 30 to 40 deg BTDC (maximum)

Pump-Line-Nozzle (PLN) Injector for CWS

The coal-water slurry injector utilizes a shuttle plunger design as shown in Figure 19. The external package dimensions of this injector fit within the current constraints of the EUI for the 149 diesel engine. The shuttle plunger, a free-floating piston that separates the slurry from the hydraulic pulse fluid (diesel fuel), is pulsed using a standard diesel injection pump with a 12 mm diameter plunger. This high pressure pulse is transmitted through the shuttle plunger to the slurry where the pressure lifts the spring-loaded needle valve in the spray tip and allows slurry to flow through the injector nozzle. Injection stops when the shuttle plunger travels far enough to uncover a spill port and relieves the pressure. As

the pump plunger retracts on the return stroke, slurry refills the injector through a check valve, and the injection pump is refilled with diesel fuel. The slurry passages through the body to the tip have been sized to accommodate the slurry flow with acceptable pressure drop. The passages were designed to present the simplest flow path for the slurry, eliminating dead end passages, annular flow passages, and flow area changes that are often found in diesel fuel injection systems.

The shuttle plunger and spray tip needle valve are exposed to slurry. Both of these areas are lubricated with a continuous flow of high-pressure seal oil (40 wt. engine oil was used). The seal oil pressure is maintained greater than the maximum injection pressure so that the slurry does not flow back into the tight clearance areas. The leakage of seal oil either mixes with the slurry or is vented out through a return port. Detailed drawings of the injector components are included in Appendix A. Photographs of the injector components and bench test rig are included in Appendix B.

Figure 19. Pump-Line-Nozzle Injector for CWS

Included in the injector configuration is a line with a check valve that tees off the diesel supply line and connects directly to the diesel injection line (the design is shown in Figure 20). The purpose of this line is to supply diesel fuel while the pump plunger is retracting. This was found to improve filling of the injection pump, provide smoother operation and better control of the shuttle plunger, and prevent cavitation by eliminating the low-pressure part of the injector cycle. It was also speculated that the introduction of this feedback line would allow an alternate means of controlling the injected volume. By adjusting the diesel supply pressure relative to the slurry supply pressure, the rate of filling on the return stroke could be controlled. In this way, the amount of slurry injected could be controlled by the rate of filling and the time available to fill (much like a P-T injection system). Figure 21 presents data in which this was attempted, and shows that it was possible to increase the volume injected while conversely decreasing the spilled volume by increasing the pressure difference between the diesel supply and slurry supply pumps. In practice, however, this was never used because of erratic behavior of the plunger during spillage (injection rates were not consistent, and the injector seemed to switch back and forth between a mode where there was a high spill rate, and a mode where there was no spillage at all). It was found through experience that the most consistent injector behavior occurred when the pressure difference between diesel and slurry supply pumps was set high enough to insure that the barrel was completely filled at each injection.

Among a number of different spray-tip designs that were considered, the six configurations described in Table 12 were chosen for testing. It was expected that high injection pressures on the order of 100 MPa and more spray orifices would overcome the atomization problems documented with CWS (Dodge, et al., 1992).

Figure 20. Injector Test Rig Configuration

Figure 21. Injected Versus Spilled Volumes as a Function of Pressure Difference Between the Fuel Supply and Injection Pump Supply

Table 12. Description of Spray-Tips

Spray-Tip Material	Orifice Configuration	Hole Diameter (mm)	Total Hole Area (mm ²)
Standard	Single Row-7 Orifices	0.36	0.713
Standard	Two Rows-4 Orifices Each Row	0.29	0.528
M-42	Single Row-7 Orifices	0.33	0.599
H-11	Two Rows-4 Orifices Each Row	0.37	0.860
H-11	Two Rows-5 Orifices Each Row	0.33	0.855
Nitrided Titanium	Single Row-7 Orifices	0.34	0.636

PLN Injector Test Rig

Figure 20 outlines the PLN injector test rig as configured for bench testing. An electric motor was used to drive the diesel injection pump through a series of belt drives and couplings. A flywheel was included to simulate the inertia of the engine. Besides the main injection pump, three supply pumps were required in the system: 1) A 5:1 air-driven intensifier pump capable of delivering CWS to the injector at up to 3.5 MPa; 2) A 300:1 air-driven intensifier pump to supply seal oil at up to 140 MPa; and 3) A gear pump to supply diesel fuel to the injection pump at up to 1.4 MPa. The supply pressures of these three pumps were varied during bench tests to optimize the PLN injector operation.

Two different injection pump camshafts were used during this program; one with a standard single-lobe configuration, and the other with two lobes, 180 degrees apart (the lobe profile did not change). The double-lobe configuration allowed the injection pump to be turned at half engine speed so that the injector could inject at 1,900 injections/minute because the pump had been limited to a maximum speed of 1,500 rpm. Later, the maximum pump speed was increased by inserting a stiffer spring to hold the follower on the cam, so it was possible to operate with the single-lobe camshaft at up to 1,900 rpm.

Injector bench test procedures involved several steps. First, the three supply pumps were initiated at their predetermined pressure settings. With the injection pump rack set to zero delivery, the electric motor was started and set to maintain the required pump operating speed. The rack was moved and held at a predetermined setting for the duration of the test (an air cylinder and micrometer adjustable stop was used for rack control). Injections began with the rack initiation, and injection pressures were monitored using pressure transducers mounted in the diesel line and on the slurry side of the shuttle plunger. In most cases, the injected slurry was collected over the duration of the test to measure the average injected volume.

Slurry Analysis

The injection bench test data was obtained using the CQ slurry with analysis as shown in Table 13. Thermogravimetric analyses (TGA) were conducted on each slurry at various times during the program to verify that the composition described in Table 13 was not changing significantly. Appendix C contains a sample TGA data curve for each slurry. The Otisca slurry, with a different type of coal and smaller particle size was used for some of the engine tests. Initially, there was some concern over compatibility of the slurry with diesel fuel and seal oil, which might accidentally come in contact inside the injector. Compatibility tests were conducted in which a 50/50 mixture of CQ slurry and engine oil was prepared, and the viscosity of the mixture was measured. The data indicates an order of magnitude increase in viscosity of the mixture over the pure CQ slurry. Attempts were made to repeat these measurements with a CQ Slurry/diesel fuel mixture, but it was not possible to obtain a representative sample without the two phases separating. To address this potential problem, an additive, Triton X-114, was added in one percent concentration to the CQ Slurry (the Otisca slurry already contained Triton X-114 as received).

Table 13. Description of Slurries

	CQ Slurry	Otisca Slurry
Moisture (Wt. %)	49.66	47.23
Coal (Wt. %)	49.83	50.77
Additives (Wt. %)	0.51	2.00
Ash (Wt. %)	0.96	0.102
Density (kg/m ³)	1126	1127
Volume-Based Mean Particle Size (m)	12	5

Previous experience in the Cooper-Bessemer program (in which slurry and diesel fuel were allowed to come in direct contact) indicated that this additive would help alleviate compatibility problems. These concerns also played a role in the decision to use methanol as a warm-up and flush-out fuel instead of diesel fuel. Compatibility tests of methanol with slurry did not show any problem.

Bench Tests—PLN Injection System

Results obtained in this program include the measurement of injection pressures and injected volume for various injection systems conditions on the bench test rig. A total of 124 different combinations were tested with injection pressures recorded for each case. The basic goals were to provide an injected volume of approximately 400 mm³/injection with a duration around 25 crankangle degrees, and with injection pressures on the order of 100 MPa. The conditions investigated included variations in slurry, diesel and seal oil supply pressures, pump cam configuration, and pump plunger diameter. The basic conclusions can be summarized as follows.

- The single-lobe cam with a 12 mm diameter plunger was necessary to provide the required injection amount and duration. Figure 22 summarizes the volume injected data for four different pump cam/plunger configurations. The figure illustrates that the 12 mm Plunger/Single-Lobe Cam combination resulted in consistently higher volume injected.
- The most consistent injector behavior was obtained when the slurry supply pressure was set at least 1 MPa higher than the diesel supply pressure. This insured that the shuttle plunger filled completely on every stroke until it came up against its stop.
- There was only a small volume of diesel spillage under the above described conditions. This was of some concern, since it was intended that diesel spillage would provide cooling to the shuttle plunger area. However, the cooling effect due to spill was not necessary to establish steady injector performance on the bench test rig.

Figure 22. Volume of Fuel Delivered

Figure 23. Injection Pressure Traces for 17 Minute Injection Test

The bench testing successfully established conditions that would provide CWS fuel delivery, duration and pressure characteristics close to the original test goals. Satisfactory supply pressures for slurry, diesel and seal oil were determined to be 2.07 MPa, 1.03 MPa and 103.4 MPa, respectively. The final step in the bench testing process was to run the injector for a relatively long period of time to establish a steady state condition. Figure 23 presents injection pressure traces obtained 15 seconds and 17 minutes into the test. There was negligible variation in the pressure traces in terms of shape, maximum pressure and injection duration over the course of the test.

A main concern during the bench tests was whether the diesel working fluid was heating up over time. Figure 24 is a plot of the injector cap skin temperature that indicates the amount of heating that occurs in the diesel injection line. Data indicates that significant heating did occur, but the temperatures leveled off within the first five or six minutes of the test. The average volume injected for the 17-minute test was 365 mm³/injection, which was somewhat lower than the 420 mm³/injection obtained in a 2-minute test under identical conditions. This indicates the volume injected decreased during the first five minutes of the test.

Discussion of Bench Test Results

Results indicated that a consistent slurry injection obtained at high speeds with the PLN injector. CWS delivery on the order of 400 mm³/injection with injection duration of about 25 crankangle degrees and peak injection pressures of around 100 MPa were obtained. Heating of the diesel fuel was observed which led to some degradation of the CWS injection, but it reached a steady state within approximately five minutes of operation.

Mechanical Unit Injector for CWS

In addition to the pump-line-nozzle injector, a Mechanical Unit Injector (MUI) was designed and fabricated. This represents a step closer to a practical injector design for coal-fueled diesel engines. The

Figure 24. Injector Cap Temperature During 17 Minute Injection Test

injector is similar to the standard MUI for the Series 149 diesel engine, but includes a 12.7 mm diameter ceramic-coated plunger and provisions for seal oil lubrication of the plunger and needle valve.

In completing design of both the PLN and MUI systems, efforts were made to incorporate as many common parts as possible. The design for the spray tip and spring cage done by DTC are compatible with both the MUI and PLN injectors. The MUI injector has been successfully tested with diesel fuel on a unit injector test bench but was not tested on the engine.

ENGINE TEST RESULTS

Test Engine Description and Modifications

An 8V-149TI engine, rated at 746 kW (1,000 bhp) @ 1,900 rpm, was built at DDC with the basic specifications shown in Table 14. This engine was equipped with the Detroit Diesel Electronic Control (DDEC) system and electronic unit injectors (EUI) for diesel fuel. Also, several engine components were installed which are normally used for high power output Series 149 engines and for use with high sulfur content diesel fuel. These components included: plasma spray ceramic-coated pistons (compression ratio of 15), cylinder heads and exhaust valves; thermal wrap exhaust manifolds and turbocharger turbine housings; and wear-resistant ceramic-coated fire rings. The engine was tested in DDC's production engine test facilities prior to its shipment to SwRI.

This engine was installed in a test cell with necessary instrumentation to measure pressures, temperatures, air and fuel flowrates and other performance parameters. Figure 25 is a schematic cross-section of the engine that identifies the main components of the engine air-flow system, and the locations where temperature and pressure were measured. It is important to note that the engine has both a turbocharger and a blower to boost cylinder inlet pressure (the area immediately surrounding the cylinder is referred to in this report as the air box). Not shown on the figure is a bypass control valve that can be opened to bypass the air flow around the blower under certain conditions. Under normal

Table 14. Specifications for the DDC 8V-149TI Diesel Engine

Number of Cylinders	8 (V-Configuration)
Bore	146 mm (5.75 inch)
Stroke	146 mm (5.75 inch)
Displacement	19.6 liters
Compression Ratio	15:1
Piston Speed	555 m/min.
Valves Per Cylinder	4 - Exhaust
Combustion System	Direct Injection Electronic Unit Injectors
Aspiration	Turbocharged, Intercooled
Rated Power	746 kW (1000 BHP)
Rated Speed	1900 rpm
Peak Torque	3871 N.m
Peak Torque Speed	1350 rpm

Figure 25. Engine Air System

operation, that bypass control valve is set to remain closed at low-load conditions, and automatically open at approximately 75 percent load. For this program, however, the valve was controlled manually. Also shown in the figure is an intercooler immediately upstream of the blower. In some tests, the cooling water flow to that intercooler was adjusted as a means of controlling the temperature of air in the air box. Initial baseline testing was performed with all eight cylinders operating on diesel fuel. The rated power was achieved at 1,900 rpm with the temperatures and pressures within the normal operating range.

The left bank, number four cylinder (#4L) was chosen for installation of the slurry injector because it is closest to the rear of the engine where the camshaft accessory drive was used to drive the diesel injection pump. Modifications to cylinder #4L included installation of a specially designed 19:1 compression ratio ceramic-coated piston, which is consistent with previous modeling recommendations for autoignition of the slurry. A new configuration cylinder head was installed with the standard thermal barrier ceramic-coated fire deck surface and a cylinder pressure transducer port. Cylinder pressure versus crankangle data was to be obtained to compute the indicated power and heat release rates.

Several modifications were necessary to install the PLN injector in #4L cylinder. With the modified configuration head, alternate passages for cooling water had to be devised to redirect the coolant flow. Passages for the slurry inlet hose, the three high-pressure lines for the injector, the seal oil to needle valve, water cooling lines for the cylinder pressure transducer and two pressure transducer wires also had to be directed through the side plate of the engine or out through the valve cover. Also, the slurry inlet hose was fitted with a three-way valve that would allow the cylinder to be operated on methanol fuel until ready to be switched to slurry. This was to insure that combustion chamber surfaces were at high temperatures before slurry was introduced. The injector would be switched back to methanol after finishing the slurry tests so that the injector lines could be flushed clean. Methanol was chosen because it has similar volumetric energy density to the slurry and is compatible with the slurry. Photographs of the engine, test cell and injection system are included in Appendix D.

Using the engine configuration described above, a series of CWS engine tests were performed. A total of 340 runs were recorded over the course of the program, including data for the test cylinder operating on methanol, CQ Slurry, Otisca Slurry, and various mixtures of additives with the CQ Slurry. At each run, all measured temperatures, pressures and flowrates were recorded, along with high-speed cylinder pressure data from which indicated power and indicated thermal efficiency were calculated. A full accounting of the data for each run is included in Appendix E. The overall test plan was designed with the intent of accomplishing the following two goals.

- The testing would define the general operating characteristics of the CWS-fueled cylinder, and compare its performance based on power and emissions measurements to the diesel-fueled cylinders. The testing would also define the effects of air-box conditions and injection timing on combustion behavior.
- The testing would investigate various parameters that might improve the CWS combustion, and/or wear characteristics of the injector spray-tip. The parameters include various spray-tip orifice configurations, spray-tip materials, and ignition improving additives.

General Operating Characteristics

Best Run Conditions and Comparison to Diesel

Figure 26 is a cylinder pressure trace and heat release rate trace for the maximum power condition in which 0.35 g/inj. of CQ CWS was injected at 1,900 rpm. The resulting indicated power for this case was 85 kW. The seven diesel-fueled cylinders were set at their maximum power condition so that the

maximum air-box pressure (192 kPa) and a high temperature (125°C) were obtained. With injection timing set to begin at 20 degrees before TDC, an ignition delay of approximately 17.5 crankangle degrees (1.5 ms) occurred. Since the total duration of injection was approximately 25 crankangle degrees, this indicates that 70 percent of the slurry had already been injected before ignition started. This is in contrast to a typical diesel injection event in which the ignition delay is much shorter, and the rate of combustion is controlled by the rate of injection. The shape of the heat release rate curve is also different in that it exhibits no initial spike that is characteristic of premixed burning in diesel combustion. The heat release rate trace does exhibit desirable characteristics, however, in the fact that there is a sharp peak that occurs approximately 6 degrees after TDC. This is almost ideal for obtaining the maximum thermal efficiency conditions. The Figure 26 traces can be contrasted with the traces for diesel fuel in Figure 27. In this case, the diesel fuel load was much lower than the slurry load (excessive cylinder pressures prevented any higher load settings), but the traces do illustrate how the diesel fuel ignition delay was much shorter than the slurry ignition delay, resulting in high cylinder pressures and a heat release rate curve which peaked before TDC.

Gaseous emissions data were also obtained for CWS runs in which the Otisca slurry was used. Table 4 details the raw data, and corrected data results that compare the CWS gaseous emissions to DF2 emissions. The gaseous emissions were obtained by sampling the left bank exhaust emissions (which contains a mixture of the test cylinder emissions and three diesel-fueled cylinders) and comparing with the right bank exhaust emissions (which is a mixture of the four diesel-fueled cylinders on the right half of the engine). The sampling location was downstream of the turbocharger at a location where it could be assumed that the emissions of all four cylinders were well mixed. By assuming that the three diesel-fueled cylinders in the left bank have identical emissions to the cylinders in the right bank, the CWS-fueled cylinder emissions could be determined. Gaseous emissions were analyzed using

Figure 27. Cylinder Pressure and Heat Release Rate Data
for Diesel Fuel Using the Standard EUI Injector

chemiluminescence for NO_x , NDIR for CO_2 and CO , a heated total hydrocarbon analyzer for unburned hydrocarbons, and a Paramagnetic Instrument for O_2 . Ranges were set according to the federal regulations for steady-state diesel emissions. Since it is more valid to make comparisons at the same load conditions, the data in Table 15 was interpolated to calculate emissions at 45 kW, which approximately matches the load on each of the diesel cylinders. Those results are tabulated in Table 16. The results show a 3:1 reduction in NO_x emissions, while unburned hydrocarbons were doubled.

Table 16 also contains a coal combustion efficiency measurement. This was obtained by sampling directly from the test cylinder at the point where exhaust leaves the engine block and enters the exhaust manifold. Exhaust was routed through a 3 μm pore size filter that collected the solid particles. Appendix F contains photographs of the filter samples immediately following the tests. The collected sample was then analyzed for ash content. Combustion efficiency was determined by comparing the ash content of the sample versus the original ash content of the coal in the slurry, and calculating how much of the coal had to burn in order to obtain that ash content. Results indicate the 20 degree timing had slightly better combustion efficiency than the 25 degree timing. The 99.2 percent efficiency obtained at 20 degree timing is close to the practical requirement for CWS fueled engines.

Effect of Air Box Conditions

This program has shown that CWS combustion is highly sensitive to the cylinder inlet conditions. Air box temperature was varied by adjusting the cooling water flow to the heat exchanger immediately upstream of the air box. The results on CWS combustion were dramatic, even though the temperature only changed by approximately 5°C . Figures 28 and 29 present cylinder pressure and heat release rate data for three cases. The figures indicate a significant increase in peak pressure and peak heat release rate, while the ignition delay time was significantly shortened. Data was also obtained which evaluates

Table 15. Left Bank Emissions Data

Run #	Slurry Flow (g/min)	% Ash in Sample	Comp. Effic. (%)	HHC (ppm)	HHC* (ppm)	CO (ppm)	CO* (ppm)	CO ₂ (%)	CO ₂ * (%)	NO _x (ppm)	NO _x * (ppm)	O ₂ (%)	O ₂ * (%)
Injection Timing (BOI) Set at 25 Degrees BTDC													
228-229	0.1	2.9	93.62	147	255	105.5	155.6	4.02	1.47	1257.3	501.3	15.71	19.61
230-231	0.14	6.8	97.39	149	263	67.5	3.6	4.37	2.87	1304.7	690.9	15.29	17.93
232-233	0.22	3.6	94.90	147	255	69.7	12.4	4.54	3.55	1320.9	755.7	15.13	17.29
234-235	0.28	8.8	98.03	147	255	76.6	40	4.58	3.71	1323.3	765.3	15.08	17.09
Injection Timing (BOI) Set at 20 Degrees BTDC													
238-239	0.18	1.8	89.61	132	195	103.7	148.4	4.17	2.07	1233.4	405.7	15.5	18.77
244-245	0.18	18.2	99.14	147	255	101.3	138.8	4.18	2.11	1266.3	537.3	15.48	18.69
240-241	0.22	18.3	99.15	142	235	97.4	123.2	4.34	2.75	1260.5	514.1	15.3	17.97
242-243	0.27	22.8	99.35	**	**	**	**	**	**	**	**	**	**
Baseline Right Bank				111		88.88		4.87		1509.3		14.41	
*Indicates values corrected for the test cylinder by assuming that the 3 DF2 fired cylinders have constant emissions = Baseline Right Bank Emissions.													
**Indicates missing data values.													
Note: Combustion efficiency was calculated based on the amount of coal required to burn in order to provide the measured ash content in the exhaust sample.													

Table 16. Comparison of Emissions Data for Diesel-Fired and CWS-Fired Cylinders at 45 kW Brake Power

Cylinder Description	Combustion Efficiency	HHC (ppm)	CO (ppm)	CO ₂ (%)	NO _x (ppm)	O ₂ (%)
CWS-Fired Cylinder With 25° BTDC Timing	96.5	261	41.6	2.52	643.5	18.35
CWS-Fired Cylinder With 20° BTDC Timing	99.2	243	129.1	2.51	522.8	18.24
DF2-Fired Cylinders	*	111	88.8	4.87	1509.3	14.41
*This item was not measured.

Figure 28. Comparison of Cylinder Pressure Traces in Which the Air Box Temperature Was Varied, Engine Speed-1,900 rpm, Test Fuel-CQ Slurry

the effect of blower bypass setting on combustion. The blower bypass valve determines whether air entering the air box goes through the blower, or bypasses it. The valve setting, thus has a significant affect on the pressure (density) and temperature in the air box. Figures 30 and 31 present a case where closing the bypass valve resulted in a significant increase in both density and temperature in the air box. The result was also a dramatic improvement in combustion as evidenced by the increased peak pressure, increased peak heat release rate, and decreased ignition delay time.

Effect of Timing

As discussed above, CWS has a significantly longer ignition delay time than does diesel fuel, so it is expected that optimum timing will be significantly different. Timings from 40 degrees to 20 degrees before TDC beginning of injection were investigated in this program. In general, for those conditions in which combustion could be sustained, there was not an obvious trend establishing the optimum timing. Figures 32 and 33 present the indicated thermal efficiency data for two different slurries, and for all the different timings that were tried. Based on this data alone, it would be difficult to determine the

Figure 29. Comparison of Heat Release Rate Traces in Which the Air Box Temperature Was Varied, Engine Speed = 1,900 rpm, Test Fuel = CQ Slurry

Figure 30. Comparison of Cylinder Pressure Traces in Which the Blower Bypass Position Was Varied, Engine Speed = 1,900 rpm, Test Fuel = CQ Slurry

Figure 31. Comparison of Heat Release Rate Traces in Which the Blower Bypass Position Was Varied, Engine Speed = 1,900 rpm, Test Fuel = CQ Slurry

Figure 32. Indicated Thermal Efficiency Data at Different Injection Timing, CQ Slurry

Figure 33. Indicated Thermal Efficiency Data for Different Injection Timings, Otica Slurry

best timing for combustion. Figures 34 and 35, however, present cylinder pressure and heat release rate data for the maximum power points for three different timing settings. These figures illustrate how the nature of combustion and the way in which power was generated was significantly changed by timing. The 40 degree timing curves for example indicate rather poor combustion, while a significant improvement was obtained by retarding timing to 30 degrees. Unfortunately, the 30 degree timing resulted in extremely high peak cylinder pressures and a heat release rate peak that occurred before TDC. Since this "knocking" resulted in cylinder pressures above the rated capacity of the engine, it was not possible to increase the slurry fuel flow and increase the power. Further retarding the timing to 20 degrees reduced the peak pressure, moved the peak heat release rate to its ideal location after TDC, and allowed for increased slurry flow to obtain higher power conditions. The procedure, then, for determining optimum timing, was to start with a fairly advanced timing, then begin retarding it until combustion characteristics improved. When a knocking problem was encountered, the timing was further retarded until reasonable peak cylinder pressures could be obtained at the maximum slurry flow conditions. The result of that optimization procedure was that the 20 degree before TDC timing was chosen as optimum.

Effect of Slurry Flowrate

Based on the discussion above, it is reasonable to ask why slurry flowrate could not be further increased to further increase the power, and thus match the rated power of the diesel fueled cylinders. The answer to that question can be illustrated in Figure 36. The figure is a plot of indicated power versus slurry flowrate for one condition in which the power reached a maximum, and then begun to drop off. This raises the possibility of a maximum flow condition for autoignited CWS fueled engines. If there is a point at which the evaporation of water lowers the in-cylinder temperature below the autoignition temperature of the coal, then there would be a maximum amount of water that could be allowed into the cylinder. For example, Figure 36 indicates a maximum power was achieved at approximately 30 g/inj (of which 15 g/inj. is water). With a 19:1 compression ratio, and air box conditions of 135°C, 170 kPa, the isentropic compression temperature would be expected to be 857°C (assumes

Figure 34. Comparison of Cylinder Pressure Traces for the Maximum Power Point of Three Different Injection Timings

Figure 35. Comparison of Heat Release Rate Traces for the Maximum Power Points of Three Different Timings

Figure 36. Effect of Slurry Flowrate on Indicated Power

$\gamma = 1.4$), and pressure would be 9,300 kPa. If 15 g of water is then injected into the cylinder, and the air/water mixture is allowed to reach equilibrium, the final temperature of the mixture will be approximately 841°C (a total internal energy change of 2.74 kJ/kg was estimated for the water, while air was assumed to have a constant $C_v = 0.88$ kJ/kg•K). Admittedly, this is a rough calculation, but it does show that there is a significant drop in compression temperature with the injected water, and that compression temperature will decrease as the mass of injected water is increased. Since it has already been shown that the CWS combustion process is highly sensitive to temperature, this reduction in compression temperature might be enough to prevent combustion, or at least significantly increase the ignition delay time.

Low Engine Speed Tests

This program did not involve extensive testing at various engine speeds, since it was determined that the rated 1,900 rpm, high load conditions were of primary interest. A few tests were performed at a low-load, 1,100 rpm condition to verify if CWS combustion was possible. In general, lower engine speed would allow more time for combustion, however, the air box temperature and pressure were lower since the turbocharger and blower was not able to supply as much energy to the incoming air. Figure 37 presents cylinder pressure and heat release-rate data for one of these tests. Under these conditions, a more retarded timing may be optimum, but the traces do indicate satisfactory engine performance.

Parametric Studies

Effect of Spray-Tip Orifice Size and Number of Orifices on Combustion

Figure 38 contains the indicated thermal efficiencies for the different orifice configurations used in this program. The results show no obvious advantage of one configuration over any other, and suggest that the combustion process was not particularly sensitive to orifice size or number of orifices. It should also be noted that the orifice size listed in Figure 38 was the original size of each spray-tip. In some

Figure 37. Cylinder Pressure and Heat Release Rate Data for a Low-Speed Case

Figure 38. Effect of Number of Spray-Tip and Orifice Size on Indicated Thermal Efficiency

cases, that orifice area more than doubled over the course of testing without any significant change in the combustion behavior. This reiterates the point that CWS combustion in this engine was not highly sensitive to orifice size. The insensitivity of combustion to orifice configuration suggests that the CWS combustion process is not highly influenced by the primary atomization process, and may be more dependent on secondary atomization off the piston crown.

Effect of Spray-Tip Material on Wear

Table 17 contains a complete tabulation of wear data obtained in this program for each spray-tip used. Estimates are also given for both the time run on slurry, and the total mass of slurry injected through each spray tip. Table 17 also presents a wear rate based on the measured wear divided by run time (it is not clear whether run time or mass of slurry injected would be the proper normalization factor, but in this case it did not make a significant difference in the conclusions). Figure 39 summarizes this data for the different spray tip materials used. Wear rate was measured by applying a constant pressure calibration fluid through the spray-tip both before and after testing, and measuring the average change in flowrate. Pressures from 20 to 60 psi were used, and an average percentage increase in flow was determined, which was then divided by the total run-time on slurry to obtain the wear rate. Any wear measurement has an inherent amount of scatter in the data, so it is not appropriate to draw any firm conclusions from the slight differences shown in Figure 39. It does seem apparent that the H-11 material may be slightly inferior to the others, but it is obvious that none of the materials used here resulted in anywhere near an acceptable wear rate. At least two orders of magnitude improvements are needed to reach an acceptable condition.

Effect of Slurry Type and Additives on Combustion

Figure 40 plots indicated thermal efficiency data for the two slurries used in this program. The results show only a marginal difference between the two, with the CQ Slurry being slightly better. This

Table 17. Injector Spray-Tip Wear Data

Spray Tip	Run Number	Estimated Total Mass of Slurry Injected (kg)	Estimated Run Time (min.)	% Increase in Flow Area	Wear Rate (% Increase in Area/min. run time)
7-hole x 0.36 mm, # 6000685-4	30 - 100	9 (CQ)	25	2.9	0.12
7-hole x 0.36 mm, # 6000685-5	109 - 135	20 (CQ)	41	32.5	0.79
8-hole x 0.29 mm, # 6000734-2	139 - 197	45 (CQ)	100	95.9	0.96
7-hole x 0.33 mm M42-73	198 - 220	11 (Otisca)	30	25.1	0.84
8-hole x 0.29 mm, # 6000734-3	224 - 263	29 (14 Otisca, 15 CQ)	90	22.0	0.24
10-hole x 0.33 mm, H-11-1	267 - 296	14 (CQ)	45	61.9	1.38
8-hole x 0.37 mm, H-11-3	297 - 329	14 (CQ)	45	86.4	1.92
7-hole x 0.33 mm, Nitrided Titanium	330 - 340	4.5 (CQ)	15	10.7	0.71

Figure 39. Spray-Tip Orifice Wear Data

Figure 40. Indicated Thermal Efficiency Data for Two Slurries

material may be slightly inferior to the others, but it is obvious that none of the materials used here resulted in anywhere near an acceptable wear rate. At least two orders of magnitude improvements are needed to reach an acceptable condition.

Effect of Slurry Type and Additives on Combustion

Figure 40 plots indicated thermal efficiency data for the two slurries used in this program. The results show only a marginal difference between the two, with the CQ Slurry being slightly better. This is interesting since the only major difference between the two slurries was the fact that the Otisca had

Figure 41. Indicate Thermal Efficiency Data for Different Slurry Formulations

methanol) and CQ Slurry, and a 33 percent diesel preparation mixed with CQ Slurry. The diesel preparation consisted of 69 percent diesel fuel, 29 percent de-ionized water, and 2 percent Triton X-114, which was blended for two minutes before being added to the CQ Slurry. A 4 percent mixture of AVOCET and slurry was prepared, but never successfully used because of compatibility problems between the AVOCET and the slurry. In general, test cylinder behavior when these additives were used was more erratic than when the pure CQ Slurry was used. There were frequent misfires and surges in power. It was also noticed that the slurry/diesel mix tended to operate more smoothly at the lower rack settings, and seemed to enhance slurry combustion under these conditions.

SUMMARY

Economic Analysis and Market Assessment

The economic feasibility analysis predicted that the future use of coal fuel in the mine-haul truck and tow boat applications is feasible and has the potential to offer significant annual savings of up to \$100,000 per year for each vehicle. With an improvement in the cost of CWS fuel and wear-resistant engine components required for coal fuel operation, these savings are expected to increase. However, the future diesel fuel price will be critical in determining the economic feasibility. It was predicted that the inland tow boat application has greater potential than the mine-haul truck because of higher load factor and lower CWS fuel costs for the tow boat engines.

Engine Modeling

Simulation results for the 149 coal-fueled engine indicate that an average droplet size smaller than 20 microns is important to obtain high coal burnout at engine speeds of 1,900 rpm. The results predict autoignition of coal fuel at various loads at 1,900 rpm with an average droplet size of 18 microns and compression ratio of 19. The performance of the CWS injection system was expected to be crucial in

achieving acceptable coal burnout in the short time available in the 149 high-speed engine. The simulation also indicated that ignition assist or higher compression ratio may be required for lower engine loads.

Injection System and Engine Tests

A pump-line-nozzle injection system for coal-water-slurry was successfully developed and tested. The system delivered approximately 400 mm³/injection at 1,900 rpm. Injection durations were on the order of 25 crankangle degrees, with peak injection pressures of about 100 MPa.

A Detroit Diesel 8V-149TI engine was installed in a test cell, and one cylinder was tested with CWS, using the PLN system described above. The test cylinder was rebuilt with a 19:1 compression ratio piston and ceramic-coated components for operation on coal fuel. Optimum injection timing was determined to be 20 degrees before TDC, where a maximum indicated power of 85 kW was obtained on the CWS-fueled cylinder. That condition represents approximately 80 percent of the full-load power of the diesel-fueled cylinders. It was found that higher power with the CWS was not possible because of the cooling effect of injected water on the compression temperature. Excessive spray-tip orifice wear was experienced with four different spray-tip materials, while the size and number of spray-tip orifices did not have a significant affect on combustion behavior.

The successful autoignition of CWS under these conditions seems to confirm the accuracy of previous model calculations which indicated a 19:1 compression ratio was required. It is interesting to note, however, that the engine performance was not as sensitive to spray-tip orifice size, engine load, or engine speed as might be inferred from the model results. Also, the model predicted fairly long ignition delay times with an optimum injection timing around 30 degrees BTDC, whereas the actual ignition delay times were relatively short with optimum timing around 20 degrees BTDC. All of this seems to suggest that the coal was easier to ignite and burn than was predicted. It is speculated that the explanation for this behavior has to do with atomization processes in the cylinder. If, for example, the majority of spray atomizes by wall impingement, such a process might be less sensitive to the spray-tip orifice size than a process where the majority of spray undergoes primary atomization before interacting with the wall. Also, the rapid vaporization of water from the porous coal particles might serve to further enhance atomization, or even break the particles themselves into smaller sizes.

CONCLUSIONS

This program verified that autoignition of CWS in a diesel engine can be achieved at engine speeds up to 1,900 rpm by utilizing high-pressure injection near TDC in a high compression ratio engine with ceramic insulated engine parts to further raise the in-cylinder temperature. Power was limited to 80 percent of full load because of the temperature reduction associated with water evaporation, however, if means can be found of further increasing the in-cylinder temperature, these limitations might be overcome. Further development of the CWS-fueled DDC Series 149 engine would require implementation of a more economically viable MUI or EUI injection system which employs hardened spray-tip materials. Economic analysis indicates that potential markets exist for a CWS-fueled DDC 149 series diesel engine in the mine-haul truck and inland towboat applications.

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APPENDIX A
Revised Injector Component Drawings

Standard IDA 149 Needle

IDA 149 Needle with
Sharp Corner Modification

		Southwest Research Institute	
		Injector Needle	
	Even Guy	DATE	03-3932-016
	Tim Callahan	A	
		DATE 2:1	SEE

Seating surfaces (ends) must be extremely flat, parallel, ground, and lapped to 2 Helium Light Bands, or better.

Rev. A

Material: AISI 1020 Steel, or equivalent

Section A-A

Southwest Research Institute

Stack Bushing

SIZE A 03-3932-004

SCALE 2:1 SET

Seating surfaces (ends) must be extremely flat, parallel, ground, and lapped to 2 Hellum Light Bands, or better.

Rev A

EDM 2 thru holes (.0937 dia) for locating dowels.

Material: AISI 1020 Steel.
or equivalent

Section A-A

Do Not Chamfer Holes

Southwest Research Institute	
Spring Cage	
SIZE A	DWG NO. 03-3932-008
SCALE 2:1	SHEET

Rev. A

Top View

The Shuttle Plunger is to be ground from an EMD 27/64" Plunger and is surface coated with TITANIUM NITRIDE prior to fitting to the Shuttle Barrel (03-3932-009).

Do Not Chamfer Corners!

Southwest Research Institute		Shuttle Plunger	
DATE	Even Guy	SIZE	DWG NO.
	Tim Callahan	A	03-3932-003
		SCALE	SHEET
		2:1	

The Shuttle Barrel is made from a blank EMD 27/64" injector barrel that is supplied without spill holes machined. The resulting part shown below, has 100-120 millionths clearance with the Shuttle Plunger (03-3932-003).

Rev. A

Ends must be very flat, parallel, ground and lepped to an extremely fine finish (2 Helium Light Bands or better).

Section A-A

CONTACT		Southwest Research Institute	
BY	Evan Guy	Shuttle Barrel	
CHK	Tim Callahan		
APP			
DATE		SIZE	03-3932-009
		A	
		SCALE	2:1
		SHEET	981

REV. A

EDM 2 holes .0937 x .125 deep
for locating dovetails.

Enlarge this hole with EDM

Add this hole with EDM

Section A-A

Southwest Research Institute		Injector Nozzle	
Evan Guy		Dwg No. 03-3932-010	
Tim Callehan		SIZE A	
		SCALE 2:1	
		SHEET	

APPENDIX B

Photographs of Injector Components and Bench Test Rig

Exploded View of Injector

Assembled Injector

Injector and Spray Box

Exploded View of Injector

Injector Bench Rig Assembly

APPENDIX C
TGA Analyses for CQ and Otisca Slurries

Sample: FL-2003 BATCH #4

Size: 98.7170 mg

Method: ASTM D5142 PROXIMATE ANAL

Comment: PROXIMATE ANALYSIS

TGA

File: E:\FL2003\84.81

Operator: R ROBLEDO

Run Date: 18-Apr-93 07:41

TGA VS. 1A DuPont 9900

Sample: SAMPLE #3

Size: 28.5750 mg

Method: 5C/MIN TO 200

Comments: 5C/MIN TO 200C; 100MLS/MIN N2

TGA

File: A: SAMPLE3.98

Operator: C. BUTCHER

Run Date: 12/23/91 12:08

TGA V5.1A DuPont 9900

APPENDIX D

Photographs of Engine, Test Cell, and Injection System

Overall View of DDC 8V-149 Engine From the Back

Overall View of DDC 8V-149 Engine From the Front

Closer View c. CWS Injection System From the Back of the Engine

Close-Up View of CWS-Fired Cylinder With a Portion of the Valve Cover

Close-Up View of Installed Injector With Valve Cover

APPENDIX E
Engine Test Data

ENGINE PERFORMANCE DATA

RUN #	ENGINE SPEED (RPM)	TORQUE (Nm)	BRAKE POWER (kW)	BMEP (kPa)	BTE (%)	TOTAL AIR FLOW (kg/s)	DEF FLOW (kg/s)	AIR BOX DENSIT (kg/m3)	TRAP. EFFIC.	SCAV. RATIO
1	1907	3363	672	1078	36.5	1.40	0.0376	1.546	0.550	1.454
2	1907	3356	670	1076	36.2	1.41	0.0379	1.542	0.547	1.464
3	1908	3466	693	1111	36.1	1.42	0.0392	1.593	0.555	1.434
4	1212	1188	151	381	32.5	0.58	0.0095	0.665	0.396	2.219
5	1505	1191	188	382	31.4	0.82	0.0122	0.777	0.408	2.142
6	1809	1578	299	506	33.2	1.12	0.0184	0.982	0.445	1.931
7	1912	2814	563	902	36.5	1.19	0.0315	1.206	0.520	1.574
8	1913	3466	694	1111	36.2	1.43	0.0392	1.558	0.547	1.466
9	1908	3611	721	1157	35.8	1.48	0.0412	1.682	0.560	1.413
10	1907	3459	691	1109	34.5	1.30	0.0410	1.493	0.563	1.402
11	1352	942	133	302	29.3	0.35	0.0093	0.433	0.460	1.852
12	1353	1871	265	600	34.8	0.43	0.0156	0.652	0.536	1.509
13	1354	2816	399	903	36.6	0.99	0.0223	0.895	0.358	2.490
14	1353	3999	567	1282	35.6	1.20	0.0325	1.273	0.411	2.128
15	1904	952	190	305	26.0	1.13	0.0149	0.935	0.443	1.942
16	1906	1874	374	601	34.6	1.03	0.0221	0.918	0.471	1.798
17	1907	2804	560	899	36.4	1.19	0.0315	1.211	0.518	1.582
18	1908	3580	715	1147	35.9	1.47	0.0407	1.631	0.551	1.449
19	757	932	74	299	30.6	0.31	0.0049	0.117	0.084	10.706
20	994	338	35	108	16.2	0.43	0.0044	0.197	0.135	6.678
21	1002	318	33	102	18.4	0.39	0.0037	0.160	0.122	7.382
22	1003	315	33	101	19.2	0.39	0.0035	0.162	0.123	7.316
23	1004	310	33	99	18.3	0.39	0.0036	0.163	0.123	7.310
24	1004	316	33	101	19.2	0.39	0.0035	0.163	0.123	7.345
25	1353	1378	195	442	32.8	0.70	0.0122	0.484	0.276	3.269
26	1908	1375	275	441	29.6	1.21	0.0190	1.080	0.473	1.791
27	910	277	26	89	17.7	0.35	0.0031	0.131	0.100	8.960
28	815	239	20	77	17.5	0.30	0.0024	0.106	0.083	10.782
29	847	256	23	82	15.9	0.32	0.0029	0.114	0.088	10.217
30	1350	1115	158	357	24.9	0.69	0.0129	0.471	0.271	3.329
31	1354	963	137	309	23.5	0.66	0.0126	0.425	0.259	3.491
32	1356	1361	193	436	31.8	0.71	0.0126	0.508	0.284	3.174
33	1358	1289	183	413	30.8	0.73	0.0123	0.525	0.287	3.140
34	1357	1368	194	438	31.2	0.72	0.0130	0.523	0.289	3.120
35	1357	1347	191	432	32.6	0.73	0.0121	0.529	0.288	3.131
36	1906	1238	247	397	26.5	1.24	0.0193	1.121	0.475	1.781
37	1907	1255	251	402	26.9	1.21	0.0193	1.087	0.473	1.787
38	1352	1335	189	428	31.7	0.72	0.0125	0.528	0.291	3.096
39	1352	1327	188	425	31.6	0.72	0.0125	0.529	0.291	3.095
40	1352	1340	190	429	32.0	0.72	0.0124	0.528	0.290	3.106
41	1353	1322	187	424	32.0	0.72	0.0122	0.530	0.292	3.083
42	1907	1285	257	412	28.0	1.20	0.0193	1.079	0.473	1.789
43	1908	1248	249	400	27.8	1.20	0.0188	1.076	0.472	1.793
44	1908	1281	256	411	28.9	1.20	0.0184	1.071	0.471	1.797
45	1908	1309	262	420	29.3	1.15	0.0186	1.027	0.470	1.804
46	1336	1136	159	364	29.2	0.69	0.0127	0.484	0.278	3.249
47	1349	1341	189	430	32.3	0.71	0.0116	0.522	0.291	3.100
48	1348	1363	192	437	32.0	0.72	0.0119	0.524	0.291	3.100
49	1904	1381	275	443	27.4	1.19	0.0199	1.083	0.476	1.773
50	1902	994	198	319	24.6	1.15	0.0188	1.009	0.464	1.835
51	1902	1243	248	398	28.0	1.20	0.0185	1.065	0.467	1.818
52	1904	1263	252	405	28.2	1.19	0.0187	1.054	0.469	1.809

ENGINE PERFORMANCE DATA

RUN #	ENGINE SPEED (RPM)	TORQUE (Nm)	BRAKE POWER (kW)	BMEP (kPa)	BTE (%)	TOTAL AI FLOW (kg/s)	DF2 FLOW (kg/s)	AIR BOX DENSIT (kg/m3)	TRAP. EFFIC.	SCAV. RATIO
53	1904	1225	244	393	27.7	1.18	0.0187	1.055	0.470	1.806
54	1903	1300	259	417	30.0	1.18	0.0180	1.054	0.469	1.807
55	1904	1056	211	338	26.3	1.16	0.0187	1.009	0.459	1.857
56	1908	1314	263	421	29.9	1.20	0.0182	1.066	0.469	1.807
57	1906	1301	260	417	28.7	1.20	0.0189	1.071	0.471	1.801
58	1908	1301	260	417	28.9	1.19	0.0188	1.067	0.472	1.795
59	1905	1397	279	448	30.8	1.18	0.0190	1.054	0.470	1.802
60	1907	1315	263	421	29.2	1.15	0.0188	1.030	0.471	1.799
61	1905	1278	255	410	28.2	1.21	0.0189	1.064	0.466	1.822
62	1904	1327	265	425	29.4	1.20	0.0189	1.063	0.468	1.811
63	1907	1318	263	422	28.7	1.20	0.0192	1.065	0.468	1.814
64	1906	1239	247	397	28.4	1.20	0.0181	1.064	0.469	1.809
65	1907	1330	266	426	28.8	1.20	0.0194	1.057	0.467	1.820
66	1901	1179	235	378	26.7	1.20	0.0184	1.069	0.468	1.812
67	1905	1340	267	429	30.2	1.19	0.0185	1.061	0.469	1.811
68	1907	1302	260	417	29.6	1.20	0.0183	1.059	0.468	1.816
69	721	312	24	100	11.0	0.42	0.0050	0.200	0.100	9.007
70	1886	1021	202	327	25.1	1.16	0.0188	1.015	0.461	1.850
71	1887	1297	256	416	29.0	1.20	0.0182	1.072	0.469	1.810
72	1903	1295	258	415	28.7	1.15	0.0180	1.018	0.469	1.810
73	1902	1294	258	415	29.5	1.16	0.0182	1.032	0.469	1.810
74	1902	1321	263	423	29.4	1.14	0.0181	1.015	0.469	1.810
75	1903	1303	260	418	28.2	1.14	0.0187	1.012	0.468	1.816
76	1902	1317	262	422	29.8	1.13	0.0183	1.015	0.471	1.798
77	1901	1334	266	428	29.6	1.13	0.0185	1.012	0.470	1.803
78	1901	1329	265	426	29.5	1.13	0.0186	1.011	0.470	1.804
79	1903	1305	260	418	28.8	1.15	0.0186	1.023	0.469	1.809
80	1902	1355	270	434	29.9	1.12	0.0187	1.008	0.472	1.796
81	1902	1320	263	423	29.2	1.14	0.0186	1.009	0.467	1.818
82	1903	1801	359	577	34.2	1.01	0.0221	0.931	0.482	1.747
83	906	269	26	86	27.5	0.35	0.0022	0.138	0.104	8.633
84	859	252	23	81	20.1	0.33	0.0026	0.122	0.094	9.565
85	848	240	21	77	21.1	0.32	0.0024	0.119	0.093	9.657
86	1907	976	195	313	24.5	1.16	0.0186	1.000	0.459	1.861
87	1908	1298	259	416	28.7	1.17	0.0181	1.041	0.469	1.808
88	1908	1385	277	444	29.6	1.14	0.0182	1.019	0.471	1.798
89	1908	1286	257	412	28.4	1.15	0.0182	1.014	0.468	1.813
90	1907	1445	289	463	30.5	1.14	0.0183	1.014	0.468	1.812
91	1907	1432	286	459	30.3	1.11	0.0183	1.007	0.476	1.777
92	1909	1371	274	439	28.9	1.20	0.0190	1.069	0.471	1.799
93	1910	1444	289	463	30.8	1.16	0.0187	1.037	0.471	1.799
94	1909	1476	295	473	30.4	1.16	0.0190	1.044	0.474	1.784
95	1910	1395	279	447	28.8	1.14	0.0190	1.030	0.477	1.769
96	1910	1387	277	445	29.9	1.16	0.0186	1.032	0.470	1.806
97	1905	1452	290	465	30.3	1.16	0.0192	1.028	0.470	1.806
98	1909	1380	276	442	29.0	1.14	0.0191	1.028	0.473	1.787
99	1909	1435	287	460	29.0	1.14	0.0193	1.021	0.473	1.788
100	1909	1457	291	467	30.0	1.13	0.0191	1.018	0.476	1.775
101	1906	1351	270	433	28.7	1.11	0.0191	0.987	0.470	1.801
102	1904	1529	305	490	31.1	1.08	0.0193	0.969	0.471	1.797
103	1910	2064	413	662	34.2	0.96	0.0251	0.906	0.491	1.702
104	1899	1130	225	362	27.2	1.18	0.0193	1.067	0.475	1.778

ENGINE PERFORMANCE DATA

RUN #	ENGINE SPEED (RPM)	TORQUE (Nm)	BRAKE POWER (kW)	BMEP (kPa)	BTE (%)	TOTAL AIR FLOW (kg/s)	DF2 FLOW (kg/s)	AIR BOX DENSIT (kg/m ³)	TRAP. EFFIC.	SCAV. RATIO
105	1899	1477	294	473	31.2	1.032	0.0192	0.947	0.479	1.758
106	1901	1507	300	483	31.4	1.029	0.0193	0.943	0.480	1.757
107	1903	1490	297	478	31.3	1.093	0.0192	0.992	0.477	1.772
108	1906	1104	220	354	26.9	1.147	0.0191	1.033	0.474	1.785
109	1905	2334	466	748	36.6	0.840	0.0272	1.022	0.585	1.320
110	760	243	19	78	16.7	0.227	0.0027	0.101	0.099	9.086
111	1908	2300	460	737	35.3	0.858	0.0279	1.041	0.585	1.322
112	1908	2341	468	750	36.2	0.862	0.0278	1.036	0.581	1.335
113	1907	2006	401	643	33.5	0.776	0.0280	0.918	0.575	1.357
114	1903	2393	477	767	36.5	1.084	0.0282	1.109	0.521	1.573
115	1903	2121	423	680	33.1	1.584	0.0277	1.700	0.538	1.499
116	1904	2365	472	758	35.8	1.062	0.0285	1.056	0.510	1.619
117	1904	2362	471	757	35.7	1.047	0.0285	1.034	0.508	1.628
118	1904	1561	311	500	34.2	0.734	0.0192	0.623	0.452	1.896
120	1904	2325	464	745	37.3	1.047	0.0269	1.029	0.506	1.637
121	1905	2385	476	764	37.4	1.061	0.0270	1.052	0.509	1.621
122	1905	2363	471	757	37.5	1.048	0.0267	1.034	0.508	1.629
123	1905	2317	462	743	37.6	1.054	0.0266	1.031	0.504	1.644
124	1905	2389	477	766	37.9	1.061	0.0267	1.044	0.507	1.633
125	1903	2328	464	746	37.7	1.052	0.0266	1.041	0.508	1.625
126	1904	2321	463	744	36.7	1.060	0.0267	1.031	0.502	1.654
127	1904	2272	453	728	36.2	1.061	0.0264	1.050	0.509	1.625
128	1904	2323	463	745	37.7	1.053	0.0266	1.027	0.503	1.649
129	1905	2315	462	742	37.0	1.046	0.0265	1.079	0.524	1.558
130	1904	2302	459	738	35.6	1.033	0.0274	1.002	0.501	1.659
131	1904	2262	451	725	35.9	1.052	0.0266	1.022	0.502	1.655
132	1903	1947	388	624	31.4	1.552	0.0260	1.558	0.514	1.602
133	1903	2071	413	664	32.9	1.552	0.0260	1.536	0.508	1.626
134	1903	2058	410	660	32.4	1.548	0.0263	1.543	0.511	1.614
135	1900	1468	292	470	29.7	1.412	0.0197	1.335	0.491	1.704
139	1904	1306	260	419	28.3	1.311	0.0189	1.200	0.480	1.758
140	1906	1298	259	416	29.1	1.256	0.0185	1.111	0.467	1.816
141	1904	1377	275	441	29.2	1.283	0.0196	1.139	0.469	1.811
144	1904	1345	268	431	29.0	1.319	0.0191	1.194	0.475	1.777
145	1904	1341	267	430	29.3	1.333	0.0190	1.213	0.478	1.766
146	1905	1407	281	451	29.4	1.366	0.0193	1.258	0.482	1.746
147	1905	1764	352	565	33.7	1.496	0.0228	1.460	0.504	1.647
149	1903	3450	688	1106	36.3	1.410	0.0397	1.581	0.555	1.435
150	1902	3514	700	1126	37.2	1.449	0.0394	1.660	0.562	1.405
151	1903	3470	692	1112	37.5	1.463	0.0396	1.665	0.560	1.415
152	1903	3490	695	1119	37.7	1.461	0.0396	1.633	0.553	1.440
153	1898	3568	709	1144	37.8	1.450	0.0391	1.666	0.563	1.404
154	1898	3579	711	1147	38.2	1.478	0.0398	1.686	0.560	1.414
155	1898	3529	701	1131	37.7	1.455	0.0397	1.682	0.565	1.396
156	1897	3492	694	1119	37.3	1.460	0.0396	1.677	0.562	1.406
157	1898	3486	693	1117	37.3	1.470	0.0396	1.684	0.562	1.408
158	1897	3537	703	1134	37.8	1.487	0.0396	1.692	0.559	1.418
159	1898	3433	682	1100	36.6	1.461	0.0397	1.663	0.559	1.418
160	1903	1151	229	369	28.0	1.241	0.0191	1.110	0.471	1.799
161	1903	1484	296	476	30.3	1.357	0.0199	1.248	0.481	1.750
162	1903	1503	300	482	31.4	1.347	0.0193	1.245	0.483	1.741
163	1902	1504	300	482	30.5	1.361	0.0199	1.251	0.481	1.751

ENGINE PERFORMANCE DATA

RUN #	ENGINE SPEED (RPM)	TORQUE (Nm)	BRAKE POWER (kW)	BMEP (kPa)	BTE (%)	TOTAL AIR FLOW (kg/s)	DF2 FLOW (kg/s)	AIR BOX DENSIT (kg/m3)	TRAP. EFFIC.	SCAV. RATIO
164	1903	1460	291	468	29.8	1.355	0.0198	1.257	0.484	1.734
165	1902	1397	278	448	30.9	1.282	0.0190	1.148	0.471	1.799
166	1903	1430	285	458	31.7	1.283	0.0190	1.143	0.469	1.806
167	1904	1830	365	587	31.6	1.412	0.0251	1.343	0.494	1.690
168	1903	1756	350	563	30.2	1.422	0.0251	1.339	0.490	1.708
169	1902	1844	367	591	31.9	1.417	0.0250	1.338	0.491	1.705
170	1903	2286	456	733	32.2	1.586	0.0312	1.582	0.511	1.613
171	1904	2284	455	732	32.4	1.596	0.0310	1.596	0.512	1.609
172	1904	2678	534	858	36.2	1.135	0.0316	1.145	0.516	1.594
173	1904	2673	533	857	36.5	1.137	0.0313	1.153	0.518	1.586
174	1901	1375	274	441	28.9	1.294	0.0191	1.172	0.475	1.777
175	1901	1708	340	547	26.7	1.481	0.0250	1.451	0.504	1.644
176	1901	1722	343	552	26.9	1.482	0.0250	1.458	0.506	1.637
177	1902	1727	344	554	27.1	1.482	0.0249	1.446	0.503	1.650
178	1899	1760	350	564	30.0	1.417	0.0250	1.348	0.493	1.696
179	1899	1802	358	578	31.1	1.429	0.0247	1.371	0.496	1.681
180	1899	1810	360	580	31.2	1.428	0.0246	1.371	0.496	1.679
181	1898	1883	374	604	31.7	1.450	0.0247	1.399	0.498	1.673
182	1899	1872	372	600	31.8	1.454	0.0244	1.405	0.499	1.668
183	1900	1909	380	612	31.9	1.464	0.0245	1.431	0.503	1.649
184	1898	1862	370	597	31.0	1.469	0.0246	1.428	0.501	1.659
185	1898	1741	346	558	28.9	1.474	0.0245	1.436	0.501	1.656
186	1899	1704	339	546	28.4	1.480	0.0244	1.432	0.499	1.667
187	1897	1741	346	558	28.8	1.474	0.0245	1.430	0.500	1.664
188	1898	1669	332	535	27.5	1.480	0.0247	1.446	0.503	1.651
189	1899	1756	349	563	30.7	1.405	0.0246	1.340	0.494	1.691
190	1903	1843	367	591	30.7	1.446	0.0254	1.380	0.495	1.686
191	1905	1839	367	589	31.2	1.458	0.0248	1.413	0.501	1.659
192	1904	1817	362	582	30.9	1.458	0.0248	1.410	0.500	1.664
193	1904	1879	375	602	31.9	1.472	0.0246	1.424	0.500	1.662
194	1904	1855	370	595	31.1	1.466	0.0250	1.426	0.502	1.653
195	1903	1810	361	580	30.2	1.495	0.0249	1.470	0.506	1.637
196	1904	1717	342	550	28.5	1.475	0.0251	1.462	0.509	1.623
197	1904	1864	372	597	29.9	1.468	0.0258	1.417	0.499	1.665
198	797	264	22	85	0.0	0.299	0.002	0.113	0.088	10.203
199	1906	1480	295	474	0.0	1.393	0.024	1.308	0.489	1.711
200	1905	1804	360	578	0.0	1.473	0.024	1.408	0.496	1.682
201	1906	1781	355	571	0.0	1.485	0.024	1.430	0.499	1.669
202	1906	1848	369	592	0.0	1.498	0.025	1.434	0.496	1.679
203	1906	1859	371	596	0.0	1.502	0.024	1.454	0.501	1.658
204	1906	1853	370	594	0.0	1.449	0.025	1.465	0.517	1.589
205	1907	1849	369	593	0.0	1.513	0.024	1.462	0.500	1.662
206	1897	1847	367	592	0.0	1.529	0.025	1.485	0.500	1.662
207	1905	1863	372	597	0.0	1.522	0.024	1.502	0.508	1.629
208	1903	1683	335	539	0.0	1.531	0.025	1.509	0.507	1.632

ENGINE PERFORMANCE DATA

RUN #	ENGIN SPEED (RPM)	TORQU (Nm)	BRAKE POWER (kW)	BMEP (kPa)	BTE (%)	TOTAL AI FLOW (kg/s)	DF2 FLOW (kg/s)	AIR BOX DENSIT (kg/m3)	TRAP. EFFIC.	SCAV. RATIO
209	1907	1757	351	563	30.4	1.468	0.024	1.402	0.496	1.681
210	1904	1777	354	570	30.5	1.462	0.025	1.404	0.497	1.675
211	1905	1783	356	571	30.6	1.471	0.025	1.412	0.497	1.675
212	1905	1766	352	566	30.3	1.479	0.025	1.426	0.499	1.667
213	1905	1771	353	568	30.9	1.479	0.025	1.411	0.495	1.685
214	1905	1842	367	590	31.2	1.483	0.025	1.428	0.498	1.670
215	1904	1836	366	588	31.4	1.483	0.025	1.427	0.498	1.670
216	1905	1843	368	591	31.1	1.505	0.025	1.450	0.499	1.668
217	1905	1871	373	600	31.5	1.491	0.025	1.442	0.500	1.661
218	1905	1753	350	562	30.8	1.451	0.025	1.389	0.496	1.679
219	1904	1754	350	562	30.7	1.451	0.025	1.392	0.497	1.676
221	1902	1758	350	563	30.8	1.415	0.025	1.365	0.499	1.669
222	1902	1785	356	572	31.2	1.423	0.025	1.367	0.497	1.675
223	1885	1532	302	491	27.1	1.363	0.025	1.315	0.495	1.684
224	1905	1573	314	504	29.6	1.403	0.025	1.342	0.496	1.680
225	1905	1561	311	500	30.0	1.416	0.024	1.353	0.496	1.682
226	1906	1751	349	561	30.8	1.492	0.025	1.446	0.501	1.658
227	1906	1739	347	557	30.7	1.488	0.025	1.441	0.501	1.658
228	1899	1722	342	552	30.0	1.470	0.025	1.423	0.499	1.667
229	1906	1761	351	564	31.3	1.499	0.025	1.447	0.500	1.664
230	1906	1886	376	604	31.9	1.436	0.025	1.489	0.526	1.549
231	1907	1842	368	590	31.4	1.515	0.025	1.477	0.504	1.647
232	1907	1899	379	609	31.7	1.544	0.025	1.516	0.506	1.635
233	1905	1935	386	620	32.1	1.522	0.025	1.513	0.510	1.617
234	1907	1903	380	610	31.4	1.543	0.025	1.518	0.507	1.632
235	1906	1904	380	610	31.4	1.535	0.025	1.513	0.507	1.630
236	1902	1825	363	585	32.0	1.475	0.024	1.440	0.503	1.649
237	1902	1814	361	581	31.9	1.482	0.024	1.439	0.501	1.657
238	1901	1572	313	504	27.8	1.421	0.024	1.374	0.499	1.666
239	1900	1816	361	582	31.6	1.467	0.025	1.426	0.501	1.657
240	1901	1835	365	588	31.9	1.401	0.024	1.446	0.523	1.561
241	1902	1804	359	578	31.4	1.485	0.024	1.447	0.502	1.652
242	1901	1880	374	603	31.4	1.505	0.025	1.471	0.503	1.648
243	1900	1869	372	599	31.8	1.507	0.024	1.472	0.503	1.649
244	1901	1785	355	572	31.5	1.469	0.024	1.426	0.501	1.659
245	1901	1798	358	576	31.7	1.483	0.024	1.430	0.498	1.671
246	1900	2983	594	956	34.3	1.342	0.040	1.505	0.554	1.437
247	1903	3129	624	1003	34.8	1.292	0.041	1.535	0.576	1.355
248	1903	3202	638	1026	35.6	1.390	0.040	1.549	0.552	1.444
249	1902	3233	644	1036	35.9	1.385	0.040	1.548	0.553	1.440
250	1905	3279	654	1051	35.5	1.391	0.040	1.563	0.556	1.431
251	1903	3320	662	1064	35.9	1.396	0.040	1.572	0.556	1.429
252	1904	3366	671	1079	36.1	1.399	0.040	1.573	0.556	1.430
253	1900	3289	654	1054	35.2	1.395	0.040	1.568	0.555	1.433
254	1902	2948	587	945	34.0	1.324	0.040	1.469	0.551	1.451
255	1901	3264	650	1046	35.4	1.388	0.041	1.554	0.554	1.438
256	1902	3274	652	1049	35.6	1.390	0.040	1.561	0.555	1.434
257	1901	3258	649	1044	35.5	1.386	0.040	1.559	0.555	1.432
258	1903	3270	652	1048	35.7	1.390	0.040	1.564	0.556	1.430
259	1902	3363	670	1078	36.7	1.389	0.040	1.559	0.555	1.434
260	1902	3280	653	1051	35.2	1.390	0.040	1.567	0.556	1.428
261	1903	3287	655	1053	35.3	1.393	0.040	1.551	0.552	1.446

ENGINE PERFORMANCE DATA

RUN #	ENGINE SPEED (RPM)	TORQUE (Nm)	BRAKE POWER (kW)	BMEP (kPa)	BTE (%)	TOTAL AIR FLOW (kg/s)	DF2 FLOW (kg/s)	AIR BOX DENSIT (kg/m ³)	TRAP. EFFIC.	SCAV. RATIO
262	1899	3201	637	1026	34.4	1.375	0.040	1.564	0.559	1.418
263	1901	3327	662	1066	35.8	1.391	0.040	1.546	0.551	1.449
264	1904	2991	596	959	34.8	1.345	0.040	1.492	0.551	1.450
265	1907	3343	668	1071	36.2	1.427	0.040	1.599	0.555	1.433
266	1903	2971	592	952	34.6	1.305	0.040	1.465	0.555	1.433
267	1905	2937	586	941	34.6	1.295	0.040	1.445	0.553	1.441
268	1908	3280	655	1051	35.5	1.381	0.041	1.536	0.553	1.443
269	1903	1618	322	519	30.1	1.367	0.025	1.288	0.490	1.708
270	1903	1864	371	597	32.0	1.444	0.025	1.378	0.495	1.687
271	1902	1808	360	579	31.0	1.442	0.025	1.379	0.496	1.683
272	1903	1830	365	587	31.3	1.441	0.025	1.382	0.497	1.677
273	1903	1864	371	597	30.8	1.457	0.025	1.400	0.497	1.675
274	1903	2931	584	939	34.2	1.283	0.040	1.414	0.548	1.460
275	1903	3348	667	1073	35.4	1.383	0.041	1.538	0.552	1.446
276	1900	1956	389	627	31.4	1.460	0.026	1.420	0.501	1.657
277	1899	2969	590	952	34.5	1.314	0.040	1.481	0.556	1.431
278	1902	3229	643	1035	35.0	1.375	0.041	1.549	0.556	1.429
279	1901	1531	305	491	29.0	1.349	0.025	1.290	0.495	1.685
280	1900	1887	375	605	32.2	1.434	0.025	1.385	0.499	1.669
281	1900	1678	334	538	31.4	1.415	0.025	1.364	0.498	1.673
282	1899	1670	332	535	31.3	1.424	0.025	1.367	0.496	1.680
283	1901	1800	358	577	33.4	1.435	0.025	1.399	0.502	1.653
284	1890	1872	371	600	34.8	1.376	0.025	1.331	0.497	1.675
285	1900	1578	314	506	29.7	1.356	0.025	1.282	0.491	1.705
286	1901	1867	372	598	31.2	1.428	0.025	1.378	0.498	1.670
287	1884	1609	317	516	26.1	1.368	0.025	1.326	0.497	1.677
288	1878	1697	334	544	27.5	1.379	0.025	1.328	0.493	1.693
289	1894	1900	377	609	31.7	1.430	0.025	1.393	0.501	1.660
290	1891	1885	373	604	31.3	1.436	0.025	1.393	0.499	1.669
291	1897	1715	341	550	29.4	1.410	0.025	1.369	0.500	1.662
292	1895	1811	359	580	31.0	1.395	0.025	1.345	0.497	1.676
293	1900	1892	376	606	31.3	1.440	0.025	1.387	0.498	1.673
294	1902	1901	379	609	31.5	1.446	0.025	1.389	0.497	1.677
295	1901	1830	364	587	32.5	1.422	0.025	1.366	0.497	1.677
296	1902	1840	366	590	32.7	1.425	0.025	1.370	0.497	1.675
297	1898	1610	320	516	29.6	1.390	0.025	1.331	0.495	1.685
298	1898	1877	373	602	33.5	1.443	0.025	1.406	0.502	1.655
299	1887	1704	337	546	29.4	1.412	0.025	1.386	0.502	1.654
300	1885	1752	346	562	30.1	1.433	0.025	1.378	0.494	1.689
301	1896	1615	321	518	27.6	1.423	0.026	1.384	0.501	1.660
302	1899	1790	356	574	30.8	1.451	0.025	1.400	0.498	1.671
303	1899	1818	362	583	31.5	1.449	0.025	1.402	0.499	1.667
304	1898	1765	351	566	30.2	1.429	0.025	1.375	0.497	1.676
305	1897	1781	354	571	30.4	1.432	0.025	1.394	0.501	1.658
306	1898	1753	348	562	30.0	1.424	0.025	1.379	0.499	1.666
307	1897	1725	343	553	29.4	1.429	0.025	1.393	0.501	1.656
308	1897	1886	375	604	31.0	1.458	0.026	1.431	0.504	1.645
309	1897	1872	372	600	31.1	1.467	0.025	1.438	0.504	1.646
310	1890	1592	315	510	26.4	1.411	0.025	1.392	0.505	1.642
311	1879	1662	327	533	27.1	1.416	0.025	1.382	0.498	1.670
312	1894	1525	302	489	25.2	1.402	0.026	1.365	0.500	1.661
313	1899	1792	356	574	30.4	1.436	0.025	1.392	0.500	1.663

ENGINE PERFORMANCE DATA

RUN #	ENGINE SPEED (RPM)	TORQUE (Nm)	BRAKE POWER (kW)	BMEP (kPa)	BTE (%)	TOTAL AI FLOW (kg/s)	DF2 FLOW (kg/s)	AIR BOX DENSIT (kg/m3)	TRAP. EFFIC.	SCAV. RATIO
314	1874	1606	315	515	26.4	1.394	0.025	1.356	0.496	1.680
315	1893	1968	390	631	33.0	1.459	0.025	1.430	0.503	1.650
316	1903	1557	310	499	29.0	1.368	0.025	1.319	0.499	1.669
317	1904	1847	368	592	33.5	1.444	0.024	1.418	0.506	1.638
318	1904	1766	352	566	29.4	1.453	0.025	1.420	0.504	1.645
319	1903	1743	347	559	29.2	1.443	0.025	1.409	0.503	1.648
320	1904	1817	362	582	30.7	1.455	0.025	1.418	0.503	1.650
321	1894	1487	295	477	24.9	1.388	0.025	1.361	0.503	1.648
322	1903	1878	374	602	30.6	1.471	0.025	1.446	0.506	1.637
323	1904	1853	369	594	30.3	1.481	0.025	1.458	0.506	1.634
324	1885	1894	374	607	31.5	1.429	0.025	1.400	0.501	1.659
325	1897	1785	355	572	29.7	1.449	0.025	1.429	0.506	1.637
326	1903	1937	386	621	31.2	1.494	0.025	1.466	0.505	1.639
327	1902	1941	387	622	31.4	1.490	0.025	1.482	0.510	1.619
328	1903	1907	380	611	30.7	1.487	0.025	1.466	0.507	1.632
329	1902	1870	372	599	30.2	1.489	0.025	1.468	0.507	1.633
330	1906	1830	365	587	30.1	1.392	0.026	1.335	0.497	1.675
331	1907	1836	367	588	30.8	1.395	0.025	1.331	0.495	1.684
332	1343	2153	303	690	34.2	0.815	0.020	0.729	0.350	2.549
333	1353	2250	319	721	37.0	0.854	0.019	0.727	0.337	2.657
334	1085	827	94	265	23.0	0.482	0.008	0.280	0.186	4.859
335	1082	883	100	283	26.1	0.484	0.007	0.281	0.186	4.867
336	1095	1095	126	351	33.4	0.496	0.008	0.289	0.188	4.801
337	1096	1040	119	333	32.4	0.495	0.007	0.291	0.190	4.762
338	906	1220	116	391	33.4	0.393	0.007	0.202	0.137	6.585
339	906	1195	113	383	31.9	0.395	0.007	0.199	0.134	6.699
340	905	1188	113	381	31.9	0.392	0.007	0.202	0.137	6.565

TEST CYLINDER CONDITIONS

RUN #	TEST FUEL	TEST FUE FLOW (kg/s)	BOI OF TEST CYL. (DBTDC)	TEST AIR FLOW (kg/s)	CHR (kJ)	APPARE COMB.EF (%)	IND. POWE (kW)	IMEP (kPa)	ITE (%)	PEAK CY PRESSUR (kPa)	BOSCH S (5-PULL) LB.RB
1	DF2	0.0054	N/A	0.18	*	*	*	*	*	*	**
2	DF2	0.0054	N/A	0.18	*	*	*	*	*	*	**
3	DF2	0.0056	N/A	0.18	*	*	*	*	*	*	**
4	DF2	0.0014	N/A	0.07	*	*	*	*	*	*	**
5	DF2	0.0017	N/A	0.10	*	*	*	*	*	*	**
6	DF2	0.0026	N/A	0.14	*	*	*	*	*	*	**
7	DF2	0.0045	N/A	0.15	*	*	*	*	*	*	**
8	DF2	0.0056	N/A	0.18	*	*	*	*	*	*	**
9	DF2	0.0059	N/A	0.19	*	*	*	*	*	*	**
10	DF2	0.0059	N/A	0.16	*	*	*	*	*	*	**
11	DF2	0.0013	N/A	0.04	*	*	*	*	*	*	**
12	DF2	0.0022	N/A	0.05	*	*	*	*	*	*	**
13	DF2	0.0032	N/A	0.12	*	*	*	*	*	*	**
14	DF2	0.0046	N/A	0.15	*	*	*	*	*	*	**
15	DF2	0.0021	N/A	0.14	*	*	*	*	*	*	**
16	DF2	0.0032	N/A	0.13	*	*	*	*	*	*	**
17	DF2	0.0045	N/A	0.15	*	*	*	*	*	*	**
18	DF2	0.0058	N/A	0.18	*	*	*	*	*	*	**
19	DF2	0.0007	N/A	0.04	*	*	*	*	*	*	**
20	DF2	0.0006	N/A	0.05	*	*	*	*	*	*	**
21	DF2	0.0005	N/A	0.05	*	*	*	*	*	*	**
22	DF2	0.0005	N/A	0.05	*	*	*	*	*	*	**
23	DF2	0.0005	N/A	0.05	*	*	*	*	*	7377	**
24	DF2	0.0005	N/A	0.05	*	*	*	*	*	7403	**
25	DF2	0.0017	N/A	0.09	*	*	*	*	*	11583	**
26	DF2	0.0027	N/A	0.15	*	*	*	*	*	15268	**
27	DF2	0.0004	N/A	0.04	*	*	*	*	*	5732	**
28	DF2	0.0003	N/A	0.04	*	*	*	*	*	5623	**
29	DF2	0.0004	N/A	0.04	*	*	*	*	*	109	**
30	DF2	0.0019	72	0.09	3.017	83.7	21	382	26.0	17499	**
31	DF2	0.0009	72	0.08	0.875	48.7	9	160	21.8	10957	**
32	METH	0.0034	72	0.09	1.757	58.2	19	338	27.5	13939	**
33	METH	0.0034	72	0.09	1.910	63.4	19	344	28.0	14532	**
34	METH	0.0035	72	0.09	1.943	63.0	23	410	32.6	13499	**
35	METH	0.0035	72	0.09	2.126	69.0	24	430	34.2	13890	**
36	METH	0.0053	72	0.16	2.189	65.6	27	344	25.3	18784	**
37	METH	0.0053	72	0.15	2.276	68.2	27	349	25.6	18506	**
38	METH	0.0030	38	0.09	1.890	70.3	23	410	37.3	12139	**
39	METH	0.0030	38	0.09	1.941	72.2	23	421	38.4	12120	**
40	METH	0.0031	38	0.09	1.968	71.6	24	426	37.9	12142	**
41	METH	0.0031	38	0.09	1.912	69.6	23	410	36.6	12180	**
42	METH	0.0046	35	0.15	2.019	69.4	35	448	37.7	15337	**
43	METH	0.0046	35	0.15	2.082	71.6	36	461	38.8	15347	**
44	METH	0.0048	35	0.15	2.075	69.1	35	455	37.1	15210	**
45	METH	0.0048	35	0.14	2.089	69.6	36	463	37.7	15080	**
46	NONE	0.0000	N/A	0.09	*****	ERR	-6	-112	ERR	6720	**
47	METH	0.0045	37	0.09	2.110	52.2	27	491	29.8	12146	**
48	METH	0.0045	37	0.09	2.126	52.6	27	493	29.8	12212	**
49	METH	0.0076	34	0.15	1.595	33.4	40	514	26.3	9781	**
50	NONE	0.0000	N/A	0.14	*****	ERR	-5	-60	ERR	9654	**
51	METH	0.0045	35	0.15	2.556	89.1	46	587	50.1	15344	**
52	CQ-C	0.0065	35	0.15	2.719	91.3	48	622	51.1	10709	**

TEST CYLINDER CONDITIONS

RUN #	TEST FUEL	TEST FUE FLOW (kg/s)	BOI OF TEST CYL. (DBTDC)	TEST AIR FLOW (kg/s)	CHR (kJ)	APPARE COMB.EF (%)	IND. POWE (kW)	IMEP (kPa)	ITE (%)	PEAK CY PRESSUR (kPa)	BOSCH S (5-PULL) LB, RB
53	METH	0.0042	35	0.15	2.448	93.2	45	574	53.5	15234	**
54	CQ-C	0.0064	35	0.15	2.636	90.6	48	616	51.9	10611	**
55	NONE	0.0000	N/A	0.15	*****	ERR	*	0	ERR	9682	**
56	METH	0.0049	27	0.15	2.606	84.2	49	625	49.4	14309	**
57	CQ-C	0.0065	27	0.15	2.557	86.4	45	574	47.5	9410	**
58	METH	0.0048	27	0.15	2.558	85.2	48	622	50.7	14005	**
59	CO-C	0.0065	27	0.15	2.466	83.3	43	551	45.5	9137	**
60	CQ-C	0.0065	27	0.14	2.228	75.3	39	495	41.0	9048	**
61	METH	0.0046	*	0.15	*	*	*	*	*	*	**
62	CQ-C	0.0064	*	0.15	*	*	*	*	*	*	**
63	CQ-C	0.0064	*	0.15	*	*	*	*	*	*	**
64	METH	0.0047	*	0.15	*	*	*	*	*	*	**
65	CQ-C	0.0064	*	0.15	*	*	*	*	*	*	**
66	METH	0.0047	*	0.15	*	*	*	*	*	*	**
67	CQ-C	0.0064	*	0.15	*	*	*	*	*	*	**
68	CQ-C	0.0064	*	0.15	*	*	*	*	*	*	**
69	NONE	0.0000	N/A	0.05	1.181	ERR	*	0	ERR	5235	**
70	NONE	0.0000	N/A	0.14	*****	ERR	*	0	ERR	9748	**
71	METH	0.0052	41	0.15	2.771	83.4	47	609	44.9	17303	**
72	CQ-C	0.0089	*	0.14	*	*	*	*	*	*	**
73	METH	0.0048	40	0.14	2.630	86.0	45	582	46.6	16832	**
74	CQ-C	0.0083	42	0.14	2.635	69.8	46	587	38.0	9620	**
75	CQ-C	0.0083	42	0.14	2.504	66.3	43	552	35.8	9274	**
76	METH	0.0048	40	0.14	2.662	87.0	45	579	46.4	16814	**
77	CQ-C	0.0071	42	0.14	2.699	82.8	47	602	45.3	10103	**
78	CQ-C	0.0071	42	0.14	2.581	79.2	44	568	42.7	9367	**
79	METH	0.0052	40	0.14	2.566	77.9	44	563	41.8	16748	**
80	CQ-C	0.0072	43	0.14	2.615	79.4	45	581	43.2	9662	**
81	CQ-C	0.0072	42	0.14	2.481	75.4	42	542	40.3	9243	**
82	METH	0.0052	40	0.13	2.580	79.4	43	557	42.0	16289	**
83	NONE	0.0000	N/A	0.04	0.012	ERR	*	0	ERR	113	**
84	NONE	0.0000	N/A	0.04	0.012	ERR	*	0	ERR	111	**
85	NONE	0.0000	N/A	0.04	0.012	ERR	*	0	ERR	111	**
86	NONE	0.0000	N/A	0.14	0.022	ERR	*	0	ERR	213	**
87	METH	0.0064	33	0.15	2.870	71.7	53	676	41.4	16967	**
88	CQ-C	0.0108	33	0.14	3.751	76.5	66	846	42.1	9398	**
89	METH	0.0064	32	0.14	2.599	64.9	48	617	37.8	16139	**
90	CQ-C	0.0111	32	0.14	3.959	78.4	72	922	44.8	12241	**
91	CQ-C	0.0111	32	0.14	3.918	77.6	70	893	43.3	10586	**
92	METH	0.0068	4	0.15	0.484	11.3	8	97	5.5	9631	**
93	METH	0.0068	20	0.15	3.268	76.3	60	775	44.3	14905	**
94	CQ-C	0.0108	22	0.15	3.825	77.5	61	781	38.7	8283	**
95	CQ-C	0.0108	22	0.14	3.415	69.2	49	633	31.5	8020	**
96	METH	0.0065	20	0.15	2.929	71.6	55	701	41.9	14100	**
97	METH	0.0067	18	0.14	3.049	72.6	58	748	43.6	13584	**
98	METH	0.0067	*	0.14	*	*	*	*	*	*	**
99	CQ-C	0.0114	*	0.14	*	*	*	*	*	*	**
100	CQ-C	0.0107	*	0.14	*	*	*	*	*	*	**
101	METH	0.0061	48	0.14	2.299	60.3	38	492	31.6	16602	**
102	CQ-C	0.0107	*	0.14	*	*	*	*	*	*	**
103	METH	0.0067	49	0.12	2.379	56.2	41	526	30.4	16750	**
104	NONE	0.0000	N/A	0.15	*****	ERR	*	0	ERR	9766	**

TEST CYLINDER CONDITIONS

RUN #	TEST FUEL	TEST FUE FLOW (kg/s)	BOI OF TEST CY (DBTDC)	TEST AIR FLOW (kg/s)	CHR (kJ)	APPARE COMB.EF (%)	IND. POWE (kW)	IMEP (kPa)	ITE (%)	PEAK CYL PRESSUR (kPa)	BOSCH S (5-PULL) L.B.RB
105	METH.	0.0061	35	0.13	2.445	63.8	44	562	35.9	15286	**
106	METH.	0.0064	35	0.13	2.649	65.9	48	616	37.5	16049	**
107	METH.	0.0064	35	0.14	2.740	68.3	50	639	39.0	16695	**
108	NONE	0.0000	N/A	0.14	-0.261	ERR	*	0	ERR	9481	**
109	METH.	0.0054	32	0.10	2.633	77.7	47	608	44.0	15934	1.3,1.9
110	NONE	0.0000	N/A	0.03	0.009	ERR	*	0	ERR	90	**
111	METH.	0.0053	32	0.11	2.424	72.7	44	560	41.1	15392	1.3,1.7
112	METH.	0.0052	32	0.11	2.297	70.9	42	536	40.5	15051	1.2,1.6
113	NONE	0.0000	N/A	0.10	-0.294	ERR	*	0	ERR	8972	**
114	METH.	0.0050	32	0.14	2.255	71.5	42	541	42.0	15700	**
115	METH.	0.0047	32	0.20	2.147	72.5	41	527	43.5	18567	**
116	METH.	0.0049	32	0.13	2.264	72.9	43	554	43.7	15906	**
117	METH.	0.0049	32	0.13	2.227	71.8	43	547	43.2	15673	**
118	METH.	0.0045	32	0.09	2.058	71.8	39	498	42.6	13152	1.3,1.4
120	METH.	0.0045	32	0.13	2.728	95.2	52	667	57.0	16667	**
121	CQ-CW	0.0080	30	0.13	3.260	88.9	57	735	49.1	9128	**
122	CQ-CW	0.0080	30	0.13	3.277	89.4	59	761	50.8	10499	**
123	METH.	0.0045	32	0.13	2.646	92.4	51	654	55.9	16523	**
124	CQ-CW	0.0080	30	0.13	3.078	83.9	57	733	48.9	10431	2.3,*
125	METH.	0.0045	31	0.13	2.662	92.9	50	650	55.5	16522	**
126	CQ-CW	0.0083	31	0.13	3.308	86.9	63	809	52.0	12849	3.4,*
127	CQ-CW	0.0083	31	0.13	1.980	52.0	32	418	26.9	7029	**
128	METH.	0.0045	32	0.13	2.644	92.3	50	645	55.2	16519	**
129	CQ-CW	0.0080	31	0.13	3.425	94.3	66	843	56.9	18318	**
130	CQ-CW	0.0080	31	0.13	2.790	76.8	53	683	46.0	10378	**
131	METH.	0.0058	32	0.13	2.597	71.6	49	624	42.1	16378	**
132	CQ-CW	0.0085	32	0.19	2.341	60.3	45	585	37.0	14722	**
133	CQ-CW	0.0097	34	0.19	3.721	83.9	71	910	50.3	18399	**
134	CQ-CW	0.0097	34	0.19	3.675	82.9	70	906	50.0	18359	**
135	CQ-CW	0.0097	34	0.18	2.636	59.4	59	763	42.1	12963	**
139	METH.	0.0057	35	0.16	3.075	85.6	50	640	43.6	17205	0.3,0.4
140	CQ-CW	0.0068	35	0.16	1.896	61.1	45	577	45.5	15041	1.2,*
141	CQ-CW	0.0070	35	0.16	2.279	71.2	43	549	42.1	16511	**
144	METH.	0.0054	20	0.16	2.630	77.3	50	641	46.2	13873	**
145	CQ-CW	0.0068	20	0.17	2.590	83.4	47	600	47.3	11364	1.5,*
146	CQ-CW	0.0089	20	0.17	3.341	82.2	61	783	47.2	12157	1.8,*
147	CQ-CW	0.0047	20	0.19	0.503	23.4	15	194	22.1	6474	4.0,*
149	METH.	0.0098	20	0.18	4.813	77.9	87	1120	44.4	16625	**
150	METH.	0.0098	20	0.18	4.962	80.2	89	1151	45.6	17197	1.4,2.4
151	CQ-CW	0.0104	20	0.18	1.545	32.5	48	618	31.8	11965	3.1,*
152	CQ-CW	0.0104	20	0.18	0.870	18.3	27	343	17.7	9740	**
153	METH.	0.0101	20	0.18	5.046	79.0	91	1178	45.2	17579	0.8,*
154	CQ-CW	0.0110	20	0.18	4.468	88.6	78	1002	48.7	14464	3.0,*
155	CQ-CW	0.0110	20	0.18	4.941	98.0	85	1101	53.5	15211	**
156	CQ-CW	0.0113	20	0.18	4.546	87.7	79	1021	48.3	14631	**
157	CQ-CW	0.0113	20	0.18	4.837	93.4	84	1082	51.2	15091	**
158	CQ-CW	0.0113	20	0.19	4.714	91.0	82	1060	50.1	14926	3.2,*
159	CQ-CW	0.0113	20	0.18	4.159	80.3	72	928	43.9	13648	**
160	NONE	0.0000	N/A	0.16	-0.461	ERR	-9	-112	ERR	10248	0.7,0.5
161	CQ-CW	0.0088	20	0.17	3.687	91.7	66	851	51.8	13438	2.8,*
162	CQ-CW	0.0088	20	0.17	3.696	91.9	66	852	51.9	13420	**
163	CQ-CW	0.0091	20	0.17	3.630	87.2	65	841	49.5	13265	2.8,*

TEST CYLINDER CONDITIONS

RUN #	TEST FUEL	TEST FUE FLOW (kg/s)	BOI OF TEST CY (DBTDC)	TEST AIR FLOW (kg/s)	CHR (kJ)	APPARE COMB.EF (%)	IND. POWE (kW)	IMEP (kPa)	ITE (%)	PEAK CYL PRESSUR (kPa)	BOSCH S (5-PULL) LB.RB
164	CO-CW	0.0091	20	0.17	3.602	86.6	65	833	49.1	13166	**
165	METH.	0.0061	20	0.16	2.863	102.6	55	711	62.4	14167	**
166	METH.	0.0061	20	0.16	2.851	102.2	55	704	61.8	14140	0.4,*
167	CO-CW	0.0056	20	0.18	2.216	86.6	41	534	51.1	12687	**
168	CO-CW	0.0056	20	0.18	2.098	82.0	38	492	47.1	11496	**
169	CO-CW	0.0056	20	0.18	2.012	78.5	36	467	44.6	11240	1.2,*
170	CO-CW	0.0054	20	0.20	2.144	86.8	40	518	51.4	13792	1.4,*
171	CO-CW	0.0054	20	0.20	2.246	91.0	43	553	54.9	14812	**
172	METH.	0.0061	20	0.14	3.125	81.3	59	758	48.3	14314	**
173	METH.	0.0061	20	0.14	3.029	78.8	58	744	47.4	14329	**
174	METH.	0.0065	22.5	0.16	2.601	63.4	53	679	40.5	12561	0.8,1.2
175	CO-CW	0.0141	22.5	0.19	1.596	24.7	28	358	13.6	7448	4.5,*
176	CO-CW	0.0141	22.5	0.19	1.368	21.2	25	317	12.0	7256	**
177	CO-CW	0.0141	22.5	0.19	1.446	22.4	26	338	12.8	7095	**
178	METH.	0.0049	22.5	0.18	1.938	62.6	38	496	39.3	13898	0.6,*
179	CO-CW	0.0068	22.5	0.18	2.432	78.1	44	562	44.2	10347	**
180	CO-CW	0.0068	25	0.18	2.359	75.7	42	542	42.6	10296	2.2,*
181	CO-CW	0.0085	25	0.18	3.255	83.5	62	796	50.0	12941	**
182	CO-CW	0.0085	25	0.18	3.177	81.6	60	778	48.9	12309	2.3,*
183	CO-CW	0.0098	25	0.18	3.259	72.6	63	813	44.4	11338	**
184	CO-CW	0.0098	25	0.18	1.809	40.3	35	456	24.9	7061	2.6,*
185	CO-CW	0.0103	25	0.18	1.105	23.4	23	299	15.5	6724	**
186	CO-CW	0.0103	25	0.19	1.838	38.9	40	520	27.0	6779	4.0,*
187	CO-CW	0.0103	25	0.18	1.393	29.5	28	361	18.7	6750	**
188	CO-CW	0.0103	25	0.18	1.357	28.7	27	349	18.1	6672	**
189	METH.	0.0042	25	0.18	2.058	77.6	40	513	47.4	14471	0.9,*
190	METH.	0.0054	22.5	0.18	2.377	69.8	47	605	43.5	14266	0.7,*
191	CO-CW	0.0079	22.5	0.18	2.537	70.3	45	576	39.1	10416	**
192	CO-CW	0.0079	22.5	0.18	2.548	70.6	44	568	38.5	10366	2.5,*
193	CO-CW	0.0084	22.5	0.18	3.038	79.2	55	702	44.8	10001	**
194	CO-CW	0.0084	22.5	0.18	2.945	76.7	53	679	43.4	9645	2.8,*
195	CO-CW	0.0089	22.5	0.19	1.723	42.3	33	419	25.2	7301	**
196	CO-CW	0.0089	22.5	0.18	1.758	43.2	34	436	26.2	7325	3.9,*
197	METH.	0.0070	22.5	0.18	3.282	74.4	62	802	44.6	14632	0.9,*
198	NONE	0.0000	N/A	0.04	-0.273	ERR	-2	-67	ERR	4440	0.3,*
199	NONE	0.0000	N/A	0.17	-0.538	ERR	-10	-122	ERR	11519	0.2,*
200	METH.	0.0058	20 22.5	0.18	2.495	68.8	49	630	42.5	15144	0.2,*
201	OT-5	0.0091	20 22.5	0.19	2.843	49.7	55	711	30.4	14964	**
202	OT-5	0.0091	20 22.5	0.19	2.777	48.5	54	699	29.9	14870	0.6,*
203	OT-5	0.0092	20 22.5	0.19	3.255	55.9	63	815	34.3	14842	**
204	OT-5	0.0092	20 22.5	0.18	3.413	58.7	66	853	35.9	15532	0.8,*
205	OT-5	0.0112	20 22.5	0.19	3.735	52.9	73	940	32.6	14952	**
206	OT-5	0.0112	20 22.5	0.19	3.477	49.0	69	894	30.9	14077	1.3,*
207	OT-5	0.0112	20 22.5	0.19	2.780	39.4	57	735	25.5	7582	**
208	OT-5	0.0112	20 22.5	0.19	1.517	21.5	28	365	12.7	6849	4.6,*

TEST CYLINDER CONDITIONS

RUN #	TEST FUEL	TEST FUE FLOW (kg/s)	BOI OF TEST CY (DBTDC)	TEST AIR FLOW (kg/s)	CHR (kJ)	APPARE COMB.EF (%)	IND. POWE (kW)	IMEP (kPa)	ITE (%)	PEAK CYL PRESSUR (kPa)	BOSCH S (5-PULL) LB.RB
209	MET	0.0054	20	0.18	2.704	79.9	51	653	47.2	14887	1.0,*
210	MET	0.0047	25	0.18	2.088	70.5	40	515	42.6	15586	0.1,*
211	MET	0.0047	25	0.18	2.106	71.2	40	516	42.7	15633	**
212	OT-5	0.0051	25	0.18	1.942	83.8	37	471	49.7	14205	**
213	OT-5	0.0051	25	0.18	1.846	79.6	34	438	46.3	13672	0.9,*
214	OT-5	0.0067	25	0.19	2.628	86.3	50	646	52.0	16132	**
215	OT-5	0.0067	25	0.19	2.614	85.8	49	630	50.6	15855	0.8,*
216	OT-5	0.0080	25	0.19	3.069	83.7	58	744	49.7	17158	**
217	OT-5	0.0080	25	0.19	2.942	80.2	56	714	47.7	16800	0.7,*
218	MET	0.0035	25	0.18	1.536	69.7	30	389	43.2	16213	**
219	MET	0.0035	25	0.18	1.535	69.6	30	391	43.4	16267	**
221	MET	0.0033	25	0.18	1.542	74.1	30	381	44.8	16290	**
222	MET	0.0033	25	0.18	1.519	73.0	29	378	44.5	16152	**
223	MET	0.0033	25	0.17	0.026	1.3	-0	-0	-0.0	5128	**
224	NON	0.0000	25	0.18	0.026	ERR	-0	-0	ERR	5120	**
225	NON	0.0000	25	0.18	0.027	ERR	-0	-0	ERR	5126	**
226	MET	0.0032	25	0.19	1.420	70.5	28	361	43.9	15948	**
227	MET	0.0032	25	0.19	1.166	57.9	23	293	35.7	14625	**
228	OT-5	0.0044	25	0.18	1.438	71.3	28	360	43.8	14767	**
229	OT-5	0.0044	25	0.19	1.575	78.4	31	400	48.8	15360	**
230	OT-5	0.0071	25	0.18	2.670	82.4	51	657	49.6	18199	**
231	OT-5	0.0071	25	0.19	2.697	83.3	52	667	50.5	17374	**
232	OT-5	0.0089	25	0.19	3.502	86.2	66	846	51.0	17685	**
233	OT-5	0.0089	25	0.19	3.493	85.9	66	843	50.8	17900	**
234	OT-5	0.0094	25	0.19	3.516	82.0	66	842	48.1	17237	**
235	OT-5	0.0094	25	0.19	3.427	79.9	64	819	46.8	16873	**
236	MET	0.0047	20	0.18	2.125	71.7	41	529	43.7	16354	**
237	MET	0.0047	20	0.19	2.103	70.9	41	525	43.4	16375	**
238	OT-5	0.0058	20	0.18	2.096	79.0	40	519	47.9	16663	**
239	OT-5	0.0058	20	0.18	2.065	77.7	40	510	47.0	15951	**
240	OT-5	0.0070	20	0.18	2.509	78.3	47	610	46.6	16835	**
241	OT-5	0.0070	20	0.19	2.567	80.2	49	631	48.3	16244	**
242	OT-5	0.0086	20	0.19	3.370	85.6	63	812	50.5	16448	**
243	OT-5	0.0086	20	0.19	3.428	87.0	64	824	51.3	16612	**
244	OT-5	0.0058	20	0.18	2.115	79.7	41	529	48.8	16029	**
245	OT-5	0.0058	20	0.19	2.113	79.6	41	525	48.5	15842	**
246	NON	0.0000	25	0.17	-0.541	ERR	-9	-113	ERR	13659	2.3,*
247	MET	0.0030	25	0.16	1.044	55.2	22	283	36.7	17983	2.5,*
248	CQ+	0.0041	25	0.17	2.252	111.7	42	543	66.0	17687	2.4,*
249	CQ+	0.0041	25	0.17	2.317	114.8	45	574	69.7	18184	**
250	CQ+	0.0073	25	0.17	2.747	76.6	51	661	45.1	18632	**
251	CQ+	0.0073	25	0.17	2.842	79.2	54	698	47.6	19236	2.4,*
252	CQ+	0.0082	25	0.17	3.413	84.7	63	814	49.4	20094	**
253	CQ+	0.0082	25	0.17	3.381	83.7	61	790	47.9	19634	2.0,*
254	NON	0.0000	20	0.17	-0.526	ERR	-9	-112	ERR	13738	3.2,*
255	MET	0.0050	20	0.17	2.327	73.7	44	569	44.1	18726	2.0,*
256	MET	0.0050	20	0.17	2.294	72.7	44	567	44.0	18592	**
257	CQ+	0.0061	20	0.17	2.502	83.3	45	585	47.7	17427	2.2,*
258	CQ+	0.0061	20	0.17	2.513	83.8	46	588	48.0	17397	**
259	CQ+	0.0061	20	0.17	3.016	100.5	55	707	57.7	17982	**
260	CQ+	0.0080	20	0.17	2.852	72.4	51	659	41.0	17644	2.2,*
261	CQ+	0.0080	20	0.17	2.842	72.2	51	654	40.7	17564	**

TEST CYLINDER CONDITIONS

RUN #	TEST FUEL	TEST FUE FLOW (kg/s)	BOI OF TEST CY (DBTDC)	TEST AIR FLOW (kg/s)	CHR (kJ)	APPARE COMB.EFF (%)	IND. POWE (kW)	IMEP (kPa)	ITE (%)	PEAK CYL PRESSUR (kPa)	BOSCH S (5-PULL) LB.RB
262	CQ+	0.0080	20	0.17	2.995	76.0	55	708	44.0	19023	**
263	CQ+	0.0080	20	0.17	3.198	81.2	59	758	47.1	19028	**
264	NON	0.0000	20	0.17	-0.509	ERR	-8	-106	ERR	13788	**
265	MET	0.0059	20	0.18	2.630	70.8	50	644	42.5	18285	**
266	NON	0.0000	20	0.16	-0.580	ERR	-8	-105	ERR	13963	**
267	NON	0.0000	20	0.16	-0.507	ERR	-9	-110	ERR	14157	3.2*
268	MET	0.0053	20	0.17	2.506	75.2	47	600	44.1	18022	2.1*
269	NON	0.0000	20	0.17	-0.676	ERR	-10	-123	ERR	12144	**
270	MET	0.0050	20	0.18	2.454	77.8	47	605	47.0	16692	0.3*
271	CQ+	0.0065	20	0.18	2.202	74.1	39	498	41.0	14465	**
272	CQ+	0.0065	20	0.18	2.327	78.3	42	545	44.9	14956	1.9*
273	CQ+	0.0091	20	0.18	3.087	74.2	57	729	42.9	16404	2.3*
274	NON	0.0000	20	0.16	-0.475	ERR	-8	-103	ERR	14353	**
275	MET	0.0070	20	0.17	3.173	71.9	60	770	42.7	19734	2.3*
276	MET	0.0068	20	0.18	2.845	66.3	54	698	39.8	16696	**
277	NON	0.0000	20	0.16	-0.525	ERR	-8	-110	ERR	14197	3.0*
278	MET	0.0049	20	0.17	2.117	68.5	41	532	42.1	18044	**
279	NON	0.0000	20	0.17	-0.680	ERR	-10	-132	ERR	12469	**
280	MET	0.0055	20	0.18	2.661	76.6	51	657	46.3	17374	0.2*
281	CQ	*	20	0.18	1.674	ERR	29	368	ERR	13499	**
282	CQ	*	20	0.18	1.626	ERR	26	341	ERR	12799	**
283	CQ	*	20	0.18	1.871	ERR	31	394	ERR	12622	**
284	CQ	*	20	0.17	1.335	ERR	21	268	ERR	12190	**
285	NON	0.0000	20	0.17	-0.618	ERR	-10	-126	ERR	12237	**
286	MET	0.0063	20	0.18	2.651	66.7	50	647	39.9	17013	**
287	CQ+	0.0076	20	0.17	1.850	39.2	33	424	22.0	14205	**
288	CQ+	0.0076	20	0.17	1.858	39.2	33	426	22.1	14088	1.6*
289	CQ+	0.0065	20	0.18	2.713	67.6	50	640	39.1	15684	**
290	CQ+	0.0065	20	0.18	3.039	75.6	55	716	43.6	16454	2.0*
291	CQ+	0.0050	20	0.18	2.191	71.1	39	508	40.4	15463	**
292	CQ+	0.0050	20	0.17	1.620	52.5	29	374	29.7	14543	2.8*
293	CQ+	0.0065	20	0.18	3.058	76.4	56	723	44.3	16327	1.5*
294	CQ+	0.0065	20	0.18	2.990	74.8	55	703	43.1	15994	**
295	CQ+	0.0024	20	0.18	2.349	159.1	42	546	90.6	14905	**
296	CQ+	0.0024	20	0.18	2.472	167.4	44	570	94.6	14757	1.4*
297	NON	0.0000	20	0.17	-0.572	ERR	-10	-135	ERR	12149	**
298	MET	0.0020	20	0.18	1.877	148.4	36	470	90.9	15876	2.0*
299	CQ	0.0042	20	0.18	1.406	72.6	24	310	39.2	13017	**
300	CQ	0.0042	20	0.18	42.896	2212.9	403	5238	661.9	118508	**
301	CQ	0.0048	20	0.18	1.653	75.1	28	363	40.3	13180	2.0*
302	CQ	0.0048	20	0.18	0.897	40.8	15	195	21.7	11958	**
303	CQ	0.0048	20	0.18	2.130	96.9	35	451	50.3	13306	1.5*
304	CQ	0.0054	20	0.18	1.664	67.2	27	349	34.6	12516	**
305	CQ	0.0054	20	0.18	1.505	60.8	24	309	30.6	11971	1.4*
306	CQ	0.0056	20	0.18	1.451	56.5	24	305	29.1	12198	2.4*
307	CQ	0.0056	20	0.18	1.242	48.3	19	244	23.3	11738	**
308	CQ	0.0076	20	0.18	1.834	52.6	31	404	28.4	12776	**
309	CQ	0.0076	20	0.18	2.665	76.5	44	565	39.7	13472	2.3*
310	CQ	0.0083	20	0.18	2.333	61.1	39	503	32.2	13833	**
311	CQ	0.0083	20	0.18	2.102	54.7	36	472	30.1	13622	2.6*
312	CQ	0.0058	20	0.18	1.174	44.1	19	246	22.7	12050	**
313	CQ	0.0058	20	0.18	0.112	4.2	2	21	1.9	11706	1.8*

TEST CYLINDER CONDITIONS

RUN #	TEST FUEL	TEST FUE FLOW (kg/s)	BOI OF TEST CY (DBTDC)	TEST AIR FLOW (kg/s)	CHR (kJ)	APPARE COMB.EF (%)	IND. POWE (kW)	IMEP (kPa)	ITE (%)	PEAK CYL PRESSUR (kPa)	BOSCH S (5-PULL) LB.RB
314	CQ	0.0073	20	0.17	3.417	100.8	57	741	53.6	16121	**
315	CQ	0.0073	20	0.18	2.779	82.8	47	605	44.2	14193	2.3,*
316	NON	0.0000	20	0.17	-0.304	ERR	-6	75	ERR	6594	**
317	MET	0.0025	20	0.18	2.334	148.1	44	562	87.4	16307	0.2,*
318	CQ+	0.0059	20	0.18	1.877	51.8	29	367	24.8	12237	**
319	CQ+	0.0059	20	0.18	1.987	54.8	32	407	27.4	13049	2.4,*
320	CQ+	0.0057	20	0.18	2.415	68.9	38	487	34.1	13455	1.7,*
321	CQ+	0.0057	20	0.17	1.670	47.4	25	324	22.5	12330	**
322	CQ+	0.0076	20	0.18	3.074	65.8	53	679	35.6	14795	**
323	CQ+	0.0076	20	0.19	2.601	55.7	46	594	31.2	14322	2.4,*
324	CQ+	0.0064	20	0.18	2.537	63.9	44	573	35.3	15336	**
325	CQ+	0.0064	20	0.18	1.990	50.4	36	459	28.5	14070	3.6,*
326	CQ+	0.0085	20	0.19	2.409	46.1	47	610	28.6	12972	**
327	CQ+	0.0085	20	0.19	1.896	36.3	36	470	22.0	12998	5.3,*
328	CQ+	0.0083	20	0.19	3.285	64.4	60	771	37.0	13992	**
329	CQ+	0.0083	20	0.19	2.770	54.3	53	678	32.5	12772	4.4,*
330	METH	0.0058	20	0.17	2.482	68.0	48	620	41.6	14907	**
331	METH	0.0058	20	0.17	2.479	67.9	48	616	41.3	14801	**
332	CQ+D	0.0018	20	0.10	0.574	25.9	8	143	15.7	9000	**
333	CQ+D	0.0018	20	0.11	0.394	17.9	5	94	10.5	7054	**
334	CQ+D	0.0025	20	0.06	2.152	56.4	23	529	33.9	9870	**
335	CQ+D	0.0025	20	0.06	2.242	58.6	25	562	36.0	9771	**
336	CQ	0.0035	20	0.06	1.194	42.9	14	308	27.1	6608	**
337	CQ	0.0035	20	0.06	1.725	62.1	20	438	38.6	8113	**
338	CQ	0.0032	20	0.05	2.037	66.3	20	545	43.4	9224	**
339	CQ	0.0032	20	0.05	1.627	52.9	16	444	35.4	7632	**
340	CQ	0.0032	20	0.05	1.762	57.3	18	480	38.2	8038	**

ENGINE FUEL/WATER/OIL TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	DF2 INLET TEMP.	DF2 RETUR TEMP.	DF2 INLET PRESS	DF2 SPILL PRESS	INJ. CAP TEMP.	WATE IN TEMP.	RB-WAT OUT TEMP.	LB-WAT OUT TEMP.	HXG WATER TEMP.	OIL GAL. TEMP.	OIL SUMP TEMP.	OIL GAL. PRESS.
1	45.1	51.2	396	115	*	76.6	84.1	82.8	*	91.6	101.1	459
2	46.3	52.0	400	117	*	76.7	84.3	83.0	*	92.3	101.7	458
3	45.5	51.1	450	143	*	76.9	85.0	83.3	*	91.7	101.7	458
4	43.0	43.3	517	220	*	62.8	75.8	76.2	*	82.7	91.1	390
5	42.0	44.7	520	214	*	63.3	76.7	76.9	*	84.3	90.9	435
6	45.5	49.7	486	184	*	76.4	82.2	81.9	*	90.2	97.0	465
7	47.6	51.9	472	158	*	77.9	84.4	83.4	*	92.6	101.5	466
8	48.7	53.3	449	144	*	77.3	85.5	83.7	*	94.1	104.0	457
9	45.1	51.1	555	205	*	77.6	85.7	83.7	*	91.0	100.5	470
10	49.8	54.6	559	211	*	78.5	86.7	85.2	*	94.4	104.8	459
11	37.5	41.0	559	240	*	64.0	76.4	77.0	*	82.0	89.0	414
12	39.8	42.8	552	234	*	69.7	79.7	79.8	*	86.4	94.8	406
13	42.0	44.1	542	226	*	77.7	83.5	83.0	*	90.4	100.3	398
14	44.3	44.8	530	214	*	76.7	85.5	83.9	*	92.7	104.6	392
15	43.6	49.2	597	251	*	75.5	81.4	81.3	*	88.7	95.9	478
16	45.6	51.1	584	239	*	79.5	83.9	83.5	*	91.6	99.3	471
17	47.7	52.5	570	225	*	78.2	84.5	83.4	*	92.8	101.4	458
18	49.5	54.7	557	210	*	80.7	89.1	87.0	*	96.7	106.7	443
19	43.0	42.2	350	134	*	62.1	75.6	76.2	*	80.6	88.4	262
20	27.0	27.3	575	256	*	42.8	37.4	38.2	*	29.6	47.2	435
21	36.3	39.0	542	249	*	74.7	78.6	79.2	*	74.2	83.9	367
22	37.5	39.1	549	251	*	51.9	74.2	75.0	*	74.5	84.0	370
23	37.4	39.0	548	253	*	56.9	74.9	75.5	*	74.6	84.5	369
24	37.5	39.1	559	256	*	51.6	74.5	75.2	*	74.3	84.1	370
25	37.7	40.5	551	240	*	63.5	77.0	77.6	*	81.3	87.7	420
26	39.8	45.9	585	244	*	75.3	82.0	81.8	*	87.5	93.5	493
27	36.9	30.6	772	369	*	61.5	69.3	68.2	*	75.8	30.8	361
28	44.7	33.8	755	369	*	57.6	74.7	73.2	*	81.6	32.7	315
29	45.1	33.5	759	370	*	63.8	66.2	64.0	*	72.2	32.1	356
30	45.5	53.1	851	370	*	69.7	78.4	80.9	*	89.3	34.8	414
31	47.6	60.1	838	369	*	64.0	76.4	50.6	*	81.5	87.3	417
32	44.2	56.9	535	211	*	62.8	76.7	-23.6	*	82.3	89.1	415
33	45.4	58.1	543	211	*	63.8	77.0	91.3	*	83.1	90.8	413
34	47.4	60.6	548	212	*	64.0	76.9	76.3	*	83.3	90.4	413
35	47.8	61.4	525	211	*	64.7	77.4	19.9	*	83.9	91.6	412
36	51.8	70.8	533	200	*	76.0	82.3	49.2	*	87.5	96.1	487
37	52.6	71.7	530	200	*	78.8	83.1	159.4	*	90.1	97.4	486
38	39.3	44.9	469	164	*	65.2	77.3	77.8	*	83.6	90.3	411
39	39.4	45.0	466	167	*	65.8	77.5	78.3	*	84.0	91.6	410
40	39.5	45.4	473	168	*	65.6	77.1	77.7	*	83.8	91.1	410
41	39.8	45.5	475	171	*	66.1	77.6	78.3	*	84.2	91.9	410
42	42.0	50.7	516	169	*	77.0	82.5	82.5	*	88.4	95.7	486
43	42.4	51.0	515	170	*	78.9	83.1	83.1	*	88.4	96.6	485
44	43.5	51.9	513	170	*	79.2	83.2	83.3	*	89.8	97.3	483
45	43.6	52.1	511	170	*	79.8	83.8	84.0	*	89.2	97.9	483
46	34.3	39.7	468	159	*	63.8	76.5	76.9	*	78.6	84.7	420
47	42.1	45.7	497	180	*	65.8	77.6	78.1	*	84.1	91.4	410
48	42.3	45.9	496	182	*	66.9	78.0	78.7	*	84.7	92.6	409
49	44.0	51.0	512	171	*	76.7	82.5	82.4	*	87.2	95.5	488
50	43.9	50.5	514	173	*	74.6	81.2	81.1	*	87.1	95.0	489
51	46.1	52.6	515	175	*	78.6	82.8	82.9	*	89.0	97.2	483
52	46.9	53.4	511	175	*	77.8	82.2	82.4	*	89.3	98.3	483

ENGINE FUEL/WATER/OIL TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	DF2 INLET TEMP.	DF2 RETUR TEMP.	DF2 INLET PRESS	DF2 SPILL PRESS	INJ. CAP TEMP.	WATE IN TEMP.	RB-WAT OUT TEMP.	LB-WAT OUT TEMP.	HXG WATER TEMP.	OIL GAL. TEMP.	OIL SUMP TEMP.	OIL GAL. PRESS.
53	47.7	53.8	515	175	*	76.8	81.8	81.8	*	89.5	97.4	483
54	47.7	53.9	521	177	*	77.4	82.1	82.2	*	89.7	97.7	483
55	43.0	49.2	516	173	*	71.6	80.0	79.8	*	84.5	91.1	494
56	45.9	51.9	520	176	*	78.5	82.9	82.8	*	87.5	96.1	486
57	46.7	52.7	520	176	*	79.8	83.9	83.9	*	89.3	97.2	484
58	48.5	54.1	520	178	*	77.1	82.1	81.9	*	89.4	97.3	483
59	48.8	54.4	517	176	*	78.2	82.7	82.6	*	89.9	97.7	482
60	49.2	54.6	519	178	*	78.4	82.8	82.7	*	89.7	97.6	482
61	47.1	53.0	520	179	*	76.7	82.2	82.1	*	88.5	95.8	484
62	48.0	53.7	519	178	*	79.4	83.6	83.6	*	89.9	97.5	482
63	48.2	53.9	523	180	*	77.3	82.0	81.9	*	89.2	97.3	482
64	48.9	54.4	521	181	*	76.5	81.9	81.7	*	89.4	97.4	482
65	49.1	54.7	518	178	*	77.9	82.5	82.5	*	90.1	98.0	481
66	49.7	55.1	518	179	*	77.6	82.3	82.2	*	89.6	98.0	480
67	49.6	55.2	523	181	*	77.7	82.6	82.6	*	89.9	98.5	480
68	49.8	55.2	525	181	*	77.2	82.0	81.9	*	89.9	98.0	480
69	27.7	28.9	436	146	*	43.9	39.9	39.3	*	33.3	47.9	433
70	41.1	50.4	517	175	82.0	73.4	80.5	80.5	76.3	85.4	92.1	493
71	44.7	53.4	520	177	88.1	78.8	84.0	84.1	78.0	89.4	97.1	482
72	47.3	54.8	522	177	91.6	79.0	83.2	83.4	78.6	90.2	98.4	482
73	47.4	55.1	525	180	89.1	78.6	82.7	82.8	78.8	89.7	97.8	483
74	47.5	55.2	522	179	91.3	78.5	82.7	82.9	79.0	90.3	98.4	482
75	47.7	55.2	521	179	90.5	78.9	83.1	83.1	79.0	90.4	98.3	482
76	47.9	55.3	523	179	89.7	78.6	82.8	82.8	78.9	89.9	97.9	482
77	48.1	55.4	525	179	91.0	79.1	83.2	83.4	79.1	90.0	98.4	481
78	48.2	55.4	523	180	90.4	78.7	82.9	83.0	79.0	90.0	98.3	481
79	48.3	55.6	524	181	88.3	78.8	82.9	83.0	79.7	90.4	97.7	482
80	48.3	55.7	523	180	91.3	78.9	83.0	83.2	79.7	90.8	98.5	481
81	48.3	55.7	523	181	90.6	78.9	83.1	83.1	79.8	90.6	98.3	481
82	48.4	55.9	517	173	89.2	78.6	83.1	83.0	79.9	90.1	98.5	480
83	32.4	32.8	479	177	70.2	49.9	70.7	75.0	70.5	66.6	79.5	353
84	33.5	33.5	452	162	75.0	53.1	73.1	75.1	70.6	67.9	81.2	337
85	33.8	33.6	441	159	75.2	56.3	73.3	75.1	70.9	68.3	81.2	333
86	40.5	42.9	617	305	84.8	73.8	80.7	80.5	69.0	86.7	93.4	489
87	43.7	44.9	619	307	94.4	79.7	83.8	83.7	69.4	89.3	98.3	482
88	45.0	45.5	625	310	95.5	78.6	82.8	82.7	69.5	90.8	98.6	482
89	44.7	45.6	620	308	99.1	78.7	82.9	82.9	70.0	90.3	98.8	481
90	44.8	45.7	620	308	98.7	78.6	82.8	82.8	69.7	90.6	98.7	480
91	44.7	45.7	623	308	101.7	79.1	83.2	83.4	70.0	90.8	98.8	481
92	43.4	45.3	644	343	97.3	79.1	83.2	83.1	69.9	88.6	97.1	484
93	45.0	46.5	642	344	101.3	78.5	82.7	82.7	69.9	90.4	98.5	481
94	45.1	46.5	645	345	101.5	78.5	82.8	82.7	69.9	90.2	98.6	481
95	45.4	46.5	643	345	101.2	78.7	83.0	82.9	69.9	89.9	98.6	481
96	45.7	46.7	639	342	98.9	78.5	82.8	82.8	69.9	90.4	98.6	481
97	43.9	46.7	652	349	95.5	78.5	82.7	82.7	71.9	90.5	98.4	482
98	44.9	47.1	646	348	99.3	78.8	83.0	82.9	72.8	90.1	98.3	482
99	45.9	47.5	643	347	101.0	79.0	83.2	83.2	73.0	90.1	98.9	481
100	46.2	47.7	645	348	100.3	78.9	83.1	83.2	72.8	89.9	98.9	481
101	42.7	47.7	664	370	*	80.0	84.3	84.6	69.6	91.5	100.7	480
102	43.8	47.6	666	370	15.5	80.0	84.2	84.8	68.4	91.6	101.1	478
103	44.1	47.7	655	370	*	79.8	84.8	85.1	68.1	92.7	102.2	477
104	30.3	41.3	677	369	26.7	80.0	83.2	83.4	62.8	87.3	95.6	483

ENGINE FUEL/WATER/OIL TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	DF2 INLET TEMP.	DF2 RETUR TEMP.	DF2 INLET PRESS	DF2 SPILL PRESS	INJ. CAP TEMP.	WATE IN TEMP.	RB-WAT OUT TEMP.	LB-WAT OUT TEMP.	HXG WATER TEMP.	OIL GAL. TEM	OIL SUMP TEMP.	OIL GAL. PRESS
105	34.3	44.2	676	369	27.0	80.5	84.1	84.8	66.0	88.7	99.5	478
106	34.8	44.7	678	369	26.7	80.0	83.7	84.3	67.1	89.6	99.3	477
107	34.7	44.4	678	369	26.4	79.5	83.2	83.6	68.9	89.6	98.2	480
108	35.0	45.0	679	369	25.9	78.6	82.4	82.3	70.0	88.9	97.3	482
109	41.7	48.3	644	384	97.6	79.0	84.3	83.9	76.6	90.0	100.9	476
110	40.1	38.7	583	380	85.1	62.6	74.8	75.3	71.0	82.0	89.3	256
111	39.5	46.6	647	385	90.7	78.8	83.9	83.6	75.5	89.9	99.1	480
112	42.8	48.7	652	387	100.5	79.0	84.5	84.2	77.5	91.8	101.6	475
113	43.4	49.2	644	385	98.7	79.2	84.6	84.1	77.8	91.7	101.7	476
114	29.6	44.1	617	208	96.6	79.3	84.8	84.2	77.7	91.1	101.4	475
115	29.8	44.4	616	209	97.9	79.3	85.2	84.1	78.0	90.9	101.5	474
116	29.7	43.4	650	227	91.6	78.8	84.1	83.4	76.5	91.9	98.8	476
117	29.8	44.1	651	228	98.7	78.4	84.0	83.5	74.5	92.7	100.1	475
118	29.9	43.2	662	237	90.8	79.6	83.1	83.6	79.6	91.4	97.8	479
120	27.8	42.4	655	226	106.4	78.9	84.2	83.9	72.6	93.5	101.3	457
121	27.5	42.3	652	225	106.8	78.9	84.1	84.0	72.8	93.4	101.3	457
122	27.8	42.3	650	224	106.8	79.0	84.3	83.9	73.7	93.6	101.5	453
123	27.5	42.5	652	224	108.8	78.7	84.1	83.7	74.6	93.6	101.7	440
124	28.1	42.5	649	225	109.0	78.5	83.9	83.5	74.6	93.6	102.3	438
125	28.5	42.7	654	227	109.6	78.5	84.0	83.5	76.4	93.9	102.9	429
126	28.6	42.9	650	225	109.7	78.4	83.8	83.3	76.9	94.0	103.0	429
127	29.0	43.2	652	227	107.9	78.6	84.1	83.6	78.0	93.8	102.7	429
128	29.3	43.5	652	226	109.1	78.9	84.4	84.0	77.0	94.4	103.3	428
129	29.2	43.5	650	226	109.6	78.8	84.3	83.8	76.4	94.3	103.4	428
130	29.2	43.7	644	224	108.8	78.6	84.3	83.7	75.9	94.3	103.5	428
131	29.4	43.2	644	234	101.4	78.4	84.1	83.4	76.4	93.7	102.6	429
132	27.3	41.7	649	237	103.1	78.0	84.1	83.1	71.4	93.6	102.7	427
133	28.2	42.6	646	236	103.1	78.9	84.8	83.9	74.0	94.1	103.1	427
134	28.4	42.9	646	237	106.4	78.7	84.7	83.9	74.2	94.3	103.5	426
135	29.4	43.5	655	248	105.1	79.1	84.1	84.1	76.6	94.1	103.0	426
139	28.8	42.3	655	237	195.4	79.0	83.1	83.1	75.9	90.6	97.3	473
140	28.4	42.6	654	237	200.2	79.2	83.6	83.4	72.7	91.8	98.7	460
141	28.4	42.6	658	238	198.5	78.5	83.3	82.9	73.4	91.6	98.9	462
144	30.0	43.6	656	239	198.7	78.8	83.7	83.5	78.3	91.4	98.4	465
145	30.1	43.8	652	238	202.1	78.3	83.6	83.5	78.7	91.6	98.6	463
146	30.3	44.2	653	238	204.4	79.0	83.0	83.7	78.1	92.0	99.3	465
147	29.6	44.1	645	232	201.3	78.1	84.2	84.0	75.3	92.4	100.9	467
149	29.7	44.8	632	209	215.1	77.6	85.6	83.9	73.4	93.6	101.9	459
150	27.9	42.6	628	205	208.2	78.1	85.3	83.9	72.1	92.4	99.7	465
151	29.0	44.4	633	208	204.9	78.4	86.0	84.5	74.2	94.5	102.9	458
152	29.2	44.7	636	211	204.0	78.5	86.1	84.7	74.8	94.6	103.1	459
153	26.8	40.3	635	208	195.8	78.1	84.7	83.5	72.0	89.8	95.8	469
154	27.6	42.2	632	209	200.6	77.9	85.2	83.9	72.5	92.6	100.2	461
155	28.0	43.0	633	209	201.7	78.0	85.6	84.2	72.9	93.4	101.4	459
156	28.2	43.4	634	207	202.0	78.0	85.6	84.3	73.0	93.7	101.8	458
157	28.5	43.6	629	210	203.8	78.1	85.8	84.5	73.3	93.9	102.2	458
158	28.6	43.8	631	208	205.3	78.3	85.9	84.6	73.5	94.2	102.5	457
159	28.8	44.2	633	210	205.0	78.2	86.0	84.7	73.5	94.4	102.7	457
160	28.7	41.9	654	235	190.5	78.0	82.2	81.9	75.0	89.4	95.5	472
161	29.5	43.3	653	236	202.3	78.8	83.5	83.5	75.6	91.5	98.4	466
162	29.6	43.5	654	236	202.5	78.7	83.3	83.3	75.7	91.6	98.6	463
163	29.6	43.5	651	237	201.7	78.8	83.4	83.4	75.9	91.8	98.8	463

ENGINE FUEL/WATER/OIL TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	DF2 INLET TEMP.	DF2 RETUR TEMP.	DF2 INLET PRESS	DF2 SPILL PRESS	INJ. CAP TEMP.	WATE IN TEMP.	RB-WAT OUT TEMP.	LB-WAT OUT TEMP.	HXG WATER TEMP.	OIL GAL. TEM	OIL SUMP TEMP.	OIL GAL. PRESS
164	29.8	43.7	648	235	200.9	78.9	83.5	83.5	76.1	91.9	99.0	461
165	28.6	42.0	656	239	187.8	78.8	83.2	83.1	72.9	90.4	96.8	466
166	28.9	42.3	650	237	191.6	78.9	83.5	83.3	73.0	90.9	97.5	464
167	30.5	44.7	643	230	178.4	78.4	84.1	83.5	74.1	92.7	100.5	452
168	30.4	44.8	650	233	180.7	78.2	84.1	83.4	74.3	92.8	100.7	448
169	30.3	44.7	646	231	182.2	78.3	84.1	83.3	74.4	92.9	100.7	447
170	30.6	45.4	639	223	179.2	78.2	85.1	83.8	75.0	93.7	102.4	436
171	30.8	45.6	640	224	178.2	78.3	85.3	83.9	75.1	94.1	102.8	433
172	30.9	45.3	640	224	187.7	78.4	84.7	83.9	75.2	94.3	103.4	430
173	30.9	45.3	639	222	192.7	78.2	84.7	83.9	75.3	94.3	103.4	429
174	28.2	42.2	653	238	202.9	78.8	83.4	83.4	70.9	92.0	99.9	434
175	29.0	43.5	645	230	245.8	79.0	84.9	84.4	71.6	94.0	102.8	428
176	29.0	43.7	643	230	247.7	79.2	85.2	84.7	71.6	94.2	103.0	427
177	29.1	44.0	648	232	247.4	79.1	85.2	84.7	71.6	94.3	103.1	427
178	28.3	42.5	646	230	199.4	79.3	84.9	84.2	71.8	92.9	101.2	431
179	28.8	43.4	647	232	206.2	78.7	84.7	84.0	71.8	93.8	102.6	428
180	28.9	43.5	645	229	207.0	78.8	84.6	83.9	71.8	93.8	102.8	428
181	29.0	43.7	647	230	209.4	79.1	84.7	84.1	71.9	94.1	103.0	427
182	29.1	43.8	648	233	211.4	79.1	85.0	84.4	71.8	94.3	103.3	427
183	29.1	44.0	647	232	214.1	78.9	84.9	84.3	71.9	94.5	103.6	426
184	29.2	44.1	645	229	218.5	79.2	85.1	84.5	72.0	94.7	103.9	426
185	29.4	44.4	644	230	224.8	79.1	85.1	84.6	72.0	94.7	103.9	426
186	29.4	44.5	645	230	227.5	79.2	85.2	84.7	72.1	94.9	104.0	426
187	29.4	44.4	642	232	229.8	79.4	85.3	84.7	72.1	94.9	104.0	426
188	29.4	44.5	643	229	230.3	79.4	85.4	84.9	72.1	95.0	104.2	426
189	29.5	44.5	646	233	214.5	78.9	84.5	83.8	72.3	94.7	104.0	425
190	28.0	41.5	645	228	189.4	79.5	84.3	83.6	72.7	90.5	97.8	436
191	28.9	43.2	647	232	205.5	79.1	84.9	84.2	72.7	93.1	101.5	430
192	29.1	43.5	642	229	208.5	79.3	85.0	84.3	72.7	93.6	102.2	429
193	29.4	44.0	646	233	212.3	79.2	85.0	84.4	72.7	94.2	103.1	427
194	29.5	44.2	643	229	214.2	79.5	85.1	84.6	72.6	94.5	103.6	427
195	29.6	44.4	643	230	221.3	79.4	85.2	84.8	72.7	94.8	104.1	426
196	29.8	44.5	644	230	228.0	79.3	85.4	84.9	72.7	95.1	104.3	426
197	30.0	45.1	647	233	220.3	79.4	85.3	84.6	72.8	95.3	104.7	424
198	26.6	37.1	375	114	188.3	64.6	75.4	76.0	72.1	84.3	92.3	248
199	26.0	39.2	648	227	178.8	79.4	84.3	83.7	69.5	89.3	95.3	439
200	26.7	40.9	646	227	193.2	78.7	84.1	83.5	68.4	92.2	100.2	431
201	27.0	42.1	649	229	217.3	78.5	84.1	83.5	67.1	93.8	102.7	427
202	27.0	42.0	645	228	220.2	78.8	84.3	83.7	67.0	94.0	102.8	426
203	26.9	42.0	644	227	221.2	78.7	84.3	83.8	66.6	94.1	103.1	425
204	26.9	42.1	646	234	221.7	78.5	84.2	83.7	67.1	94.1	103.2	425
205	26.9	42.1	645	227	221.6	78.6	84.4	83.9	68.2	94.2	103.3	425
206	27.1	42.3	643	228	221.3	78.3	84.1	83.7	68.5	94.2	103.4	425
207	27.3	42.4	643	229	222.0	78.6	84.5	84.1	68.6	94.5	103.6	425
208	27.4	42.6	643	229	229.1	78.7	84.6	84.3	68.8	94.5	103.7	425

ENGINE FUEL/WATER/OIL TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	DF2 INLET TEMP.	DF2 RETUR TEMP.	DF2 INLET PRESS	DF2 SPILL PRESS	INJ. CAP TEMP.	WATE IN TEMP.	RB-WAT OUT TEMP.	LB-WAT OUT TEMP.	HXG WATER TEMP.	OIL GAL. TEM	OIL SUMP TEMP.	OIL GAL. PRESS
209	27.5	42.7	650	230	226.7	78.6	84.3	83.6	69.3	94.2	103.3	425
210	26.0	39.8	645	226	197.0	78.4	83.7	83.1	68.8	91.0	98.7	433
211	26.4	40.6	647	226	201.6	78.5	84.0	83.3	68.9	91.9	99.9	430
212	26.9	41.3	644	227	207.6	78.4	83.9	83.3	69.1	92.7	101.1	429
213	27.1	41.6	642	225	207.5	78.6	84.1	83.3	69.2	93.0	101.5	428
214	27.2	41.9	643	228	210.3	78.4	84.0	83.3	69.3	93.3	102.0	427
215	27.3	42.0	644	229	212.4	78.4	84.1	83.4	69.6	93.5	102.3	427
216	27.5	42.3	642	228	215.5	78.4	84.0	83.5	69.8	93.7	102.6	426
217	27.8	42.6	642	227	222.1	78.4	84.0	83.5	70.1	93.9	102.9	425
218	28.2	42.4	644	228	202.0	79.6	85.0	84.3	72.2	92.6	99.5	472
219	28.3	44.1	649	229	206.1	79.3	84.7	84.0	72.3	92.6	99.7	473
221	27.2	41.6	642	225	192.2	78.3	83.7	83.0	69.7	91.0	97.7	476
222	27.5	41.9	650	229	191.3	78.4	83.9	83.0	69.8	91.3	98.1	474
223	26.6	40.9	647	224	187.5	78.2	82.9	82.2	70.5	89.1	94.8	480
224	24.0	35.7	650	224	186.4	78.4	83.5	82.9	66.9	87.8	92.3	483
225	24.4	38.1	647	223	191.9	79.1	83.7	83.0	66.9	89.4	94.9	480
226	25.4	40.3	647	226	203.9	79.5	84.5	83.9	67.9	92.2	99.0	473
227	25.6	39.8	645	225	197.4	79.4	84.3	83.8	67.7	92.4	99.3	472
228	25.8	41.0	647	226	195.4	79.8	84.7	84.1	68.3	92.9	99.8	470
229	26.2	40.8	649	226	194.4	79.6	84.7	84.1	68.9	93.0	100.0	469
230	26.4	41.5	648	234	190.9	79.5	84.7	84.1	69.4	93.1	100.3	469
231	26.4	41.5	652	227	193.6	79.5	84.8	84.3	69.8	93.2	100.3	469
232	26.8	41.9	650	227	199.8	79.5	84.8	84.3	70.0	93.3	100.5	467
233	27.0	42.1	650	228	204.6	79.4	84.8	84.3	70.7	93.4	100.7	467
234	27.2	42.4	645	227	206.7	79.4	84.8	84.4	70.7	93.4	100.7	466
235	27.3	42.5	644	228	207.7	79.4	84.9	84.4	71.2	93.5	100.8	466
236	25.0	38.8	646	223	192.5	79.4	83.9	83.4	67.9	89.4	94.9	477
237	25.3	39.3	649	225	193.9	79.1	84.2	83.7	68.3	90.3	96.2	475
238	26.2	40.9	644	225	184.2	79.4	84.3	83.8	68.2	92.2	99.0	471
239	26.6	41.5	645	227	199.1	79.4	84.5	83.9	68.9	92.7	99.8	468
240	26.9	41.9	643	232	197.3	79.5	84.6	84.0	69.8	92.9	100.1	468
241	27.1	42.1	650	228	197.7	79.4	84.7	84.1	70.3	93.1	100.3	467
242	27.5	42.1	645	226	198.8	79.3	84.6	84.2	70.6	93.2	100.5	466
243	27.6	42.9	648	230	204.7	79.3	84.9	84.4	70.7	93.3	100.6	465
244	27.9	42.9	644	227	206.1	79.8	85.0	84.4	72.1	93.5	100.7	466
245	28.2	43.0	645	227	202.8	79.5	84.8	84.3	72.2	93.4	100.7	465
246	25.5	39.0	634	204	186.2	78.3	84.6	83.1	69.2	89.8	95.9	475
247	28.0	42.3	630	211	192.5	78.3	85.5	84.0	73.1	92.3	99.6	469
248	29.4	44.0	634	209	204.9	78.3	86.0	84.4	71.5	94.6	103.1	461
249	29.4	44.9	632	207	203.4	78.4	86.2	84.5	71.4	94.7	103.2	461
250	29.3	45.0	631	209	201.7	78.3	86.1	84.5	71.0	94.8	103.4	459
251	29.4	45.5	628	207	200.1	78.4	86.2	84.6	71.0	94.8	103.4	460
252	29.3	44.9	631	207	200.4	78.3	86.2	84.6	70.4	94.9	103.5	459
253	29.3	44.9	629	206	200.0	78.4	86.1	84.5	70.3	94.9	103.6	459
254	26.3	39.7	629	201	174.9	78.6	85.0	83.6	69.7	89.3	95.0	473
255	27.5	41.7	629	205	189.4	78.3	85.6	83.9	70.0	92.0	99.2	467
256	28.1	42.4	626	204	193.6	78.8	86.0	84.3	70.2	92.8	100.2	467
257	29.0	43.8	626	206	197.4	78.5	86.1	84.4	71.0	93.8	101.9	463
258	29.3	44.4	628	205	199.8	78.7	86.2	84.6	71.2	94.1	102.3	463
259	29.7	45.0	625	205	194.8	78.9	86.6	84.9	71.8	94.6	103.0	460
260	29.9	45.4	628	205	194.5	78.6	86.4	84.6	72.2	94.7	103.3	459
261	30.3	45.4	630	206	192.6	78.8	86.6	84.9	72.1	94.7	103.3	460

ENGINE FUEL/WATER/OIL TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	DF2 INLET TEMP.	DF2 RETUR TEMP.	DF2 INLET PRESS	DF2 SPILL PRESS	INJ. CAP TEMP.	WATE IN TEMP.	RB-WAT OUT TEMP.	LB-WAT OUT TEMP.	HXG WATER TEMP.	OIL GAL. TEM	OIL SUMP TEMP.	OIL GAL. PRESS
262	30.3	45.9	631	209	192.1	78.8	86.6	85.0	72.5	95.0	103.6	458
263	30.5	45.9	630	209	194.9	79.0	86.9	85.1	73.9	95.1	103.7	458
264	27.0	39.6	629	203	178.6	77.9	84.4	83.0	71.4	89.4	95.6	470
265	28.5	42.8	631	206	188.4	78.0	85.4	83.8	72.0	92.4	100.1	463
266	27.0	41.4	627	204	194.7	77.8	84.9	83.3	68.1	91.9	99.2	456
267	27.5	41.4	627	204	180.9	78.6	85.0	83.6	71.6	91.0	97.7	463
268	29.2	43.9	631	206	197.8	78.4	86.3	84.5	72.1	93.9	102.1	455
269	25.8	38.9	648	225	175.5	72.5	81.0	80.2	69.0	85.4	90.3	467
270	26.9	40.8	644	226	197.1	79.2	84.4	83.7	68.8	90.2	96.3	457
271	27.7	42.4	644	227	214.2	79.2	84.5	83.6	68.4	92.3	99.5	452
272	27.8	42.5	647	228	212.3	79.0	84.1	83.5	68.3	92.4	99.9	450
273	27.9	42.7	643	228	207.2	78.9	84.6	83.8	68.2	92.8	100.4	447
274	26.3	40.5	634	206	196.2	77.3	84.6	83.3	67.6	89.7	95.8	441
275	27.9	42.6	627	206	203.2	78.7	86.3	84.6	67.6	94.2	102.8	425
276	28.3	43.4	641	227	203.4	79.2	84.9	83.8	67.6	93.7	101.9	423
277	25.6	39.2	632	201	181.2	79.1	85.2	83.9	68.0	90.1	96.8	433
278	27.2	41.8	629	203	191.4	78.8	86.1	84.6	68.0	93.8	102.2	424
279	28.1	42.8	644	226	201.4	80.7	85.5	84.8	69.7	92.7	99.4	430
280	28.3	43.1	641	225	203.9	79.8	85.1	84.5	70.0	93.7	101.6	426
281	28.5	43.5	642	223	194.3	79.9	85.4	84.5	70.1	94.2	102.3	426
282	28.5	43.6	634	224	179.0	79.7	85.2	84.4	70.2	94.2	102.4	424
283	28.8	43.9	640	226	204.1	79.5	85.2	84.3	70.3	94.5	103.0	424
284	28.7	43.8	641	227	181.2	79.6	85.2	84.3	70.3	94.6	102.9	424
285	27.8	42.1	641	223	197.7	79.7	84.5	83.6	70.3	91.9	98.9	431
286	28.1	42.6	638	225	200.1	79.4	84.8	83.8	70.3	93.1	100.9	428
287	28.5	43.3	640	225	183.7	79.2	84.8	83.9	70.3	94.0	102.4	424
288	28.5	43.5	641	226	178.5	79.1	84.9	84.1	70.3	94.2	102.5	423
289	28.6	43.7	638	225	179.1	79.2	84.8	84.0	70.2	94.3	102.7	424
290	28.6	43.7	636	226	183.0	79.1	84.9	84.2	70.2	94.4	102.9	423
291	28.8	43.7	638	226	184.9	79.0	84.8	84.1	70.2	94.4	103.0	424
292	28.6	43.8	637	225	196.3	79.2	84.9	84.1	70.2	94.4	102.9	424
293	28.6	43.8	638	226	194.1	79.1	84.9	84.0	70.2	94.5	103.0	424
294	28.7	43.9	639	226	195.7	79.1	84.9	84.0	70.1	94.4	103.1	424
295	28.6	43.8	639	226	194.8	78.9	84.9	84.1	70.2	94.5	103.1	424
296	28.6	43.8	639	225	190.6	78.9	84.8	84.2	70.2	94.5	103.1	425
297	26.8	40.2	643	225	189.7	79.8	84.6	84.1	71.9	90.2	96.5	434
298	27.4	41.7	639	224	194.7	79.4	84.7	84.1	71.5	92.5	100.1	427
299	28.3	43.3	637	222	201.6	79.1	84.8	84.1	71.3	94.2	102.9	423
300	28.3	43.4	641	225	202.5	79.2	85.0	84.2	71.2	94.3	102.9	422
301	28.4	43.4	644	226	202.6	79.1	84.9	84.2	71.2	94.3	103.0	423
302	28.5	43.5	636	223	193.4	79.1	84.8	84.0	71.2	94.4	103.1	424
303	28.4	43.5	636	221	181.6	79.1	84.9	84.1	71.2	94.4	103.1	424
304	28.5	43.6	635	225	179.4	79.1	84.8	84.0	71.1	94.4	103.1	424
305	28.5	43.7	640	225	176.4	79.0	85.0	84.1	71.2	94.5	103.2	424
306	28.5	43.7	637	224	180.3	79.2	84.8	84.2	71.2	94.5	103.3	424
307	28.5	43.7	637	225	186.7	79.4	85.1	84.3	71.2	94.6	103.3	423
308	28.5	43.7	641	226	185.9	79.4	85.1	84.2	71.2	94.8	103.3	423
309	28.5	43.7	637	225	191.9	79.2	85.0	84.3	71.2	94.7	103.3	423
310	28.6	44.0	636	223	200.8	79.1	85.0	84.4	71.2	94.8	103.7	422
311	28.6	43.9	636	224	203.4	79.1	84.9	84.3	71.2	94.8	103.7	422
312	28.9	44.0	636	226	183.4	79.1	84.9	84.1	71.2	94.8	103.8	423
313	28.7	44.0	638	224	179.2	79.3	85.1	84.4	71.2	95.0	103.7	423

ENGINE FUEL/WATER/OIL TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	DF2 INLET TEMP.	DF2 RETUR TEMP.	DF2 INLET PRESS	DF2 SPILL PRESS	INJ. CAP TEMP.	WATE IN TEMP.	RB-WAT OUT TEMP.	LB-WAT OUT TEMP.	HXG WATER TEMP.	OIL GAL. TEM	OIL SUMP TEMP.	OIL GAL. PRESS
314	28.6	43.8	633	223	180.3	79.0	85.0	84.2	71.2	94.8	103.5	420
315	28.6	44.0	639	224	198.4	79.2	85.1	84.4	71.2	94.9	103.8	422
316	25.5	38.6	639	219	181.6	75.8	82.4	81.7	69.5	87.3	92.8	442
317	26.3	40.1	637	221	186.5	79.7	84.8	84.1	69.8	91.1	97.9	432
318	27.1	41.7	637	223	177.5	79.4	84.9	84.2	69.7	93.3	101.2	427
319	27.2	42.0	635	224	177.2	79.5	85.1	84.4	69.6	93.6	101.7	426
320	27.5	42.4	642	225	176.9	79.4	85.0	84.4	69.7	94.0	102.3	426
321	27.7	42.7	638	226	179.8	79.7	85.3	84.6	69.6	94.4	102.9	424
322	27.9	43.0	641	227	182.9	79.7	85.2	84.6	69.6	94.7	103.3	424
323	28.0	43.2	638	225	189.9	79.9	85.5	84.9	69.7	95.0	103.6	424
324	28.0	43.2	639	225	195.1	79.8	85.5	84.8	69.3	95.0	103.7	422
325	28.1	43.3	641	226	201.0	79.7	85.5	84.9	69.8	95.0	103.8	422
326	28.1	43.6	638	223	208.3	79.7	85.6	85.1	69.8	95.2	104.0	422
327	28.2	43.6	638	224	213.5	79.9	85.6	85.2	69.8	95.3	104.2	422
328	28.2	43.7	640	226	208.6	79.7	85.5	84.9	69.9	95.3	104.2	422
329	28.2	43.7	637	223	207.0	79.8	85.5	85.1	69.9	95.3	104.4	422
330	27.7	41.9	634	222	200.1	78.0	84.0	83.2	69.5	92.1	100.0	431
331	27.8	41.9	634	223	203.5	78.1	84.0	83.1	69.5	92.4	100.4	431
332	29.3	40.7	591	224	188.7	77.0	83.2	83.2	71.7	92.4	101.4	350
333	28.9	40.3	589	218	179.8	77.2	82.8	82.6	71.7	92.0	100.8	352
334	28.5	38.8	621	248	164.9	73.5	79.7	80.4	71.8	89.5	97.4	311
335	28.2	38.0	622	246	159.5	71.3	78.5	79.3	71.8	88.2	95.9	315
336	27.4	36.6	629	248	164.2	67.3	76.4	77.4	71.9	85.1	92.1	324
337	27.4	35.9	599	248	161.4	66.9	76.3	77.2	71.8	84.8	91.7	325
338	27.1	36.9	460	160	164.2	66.4	76.9	78.0	71.8	84.1	90.7	284
339	26.9	36.3	458	157	162.6	66.4	77.0	78.1	71.7	84.1	90.5	284
340	26.8	35.7	467	162	163.5	66.3	77.0	78.0	71.7	84.0	90.3	285

ENGINE AIR SYSTEM TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RU #	RB-COM IN TEMP.	LB-COM IN TEMP.	RB-COM OUT TEMP.	LB-COM OUT TEMP.	RF-AIR BOX TEMP.	RR-AIR BOX TEMP.	LF-AIR BOX TEMP.	LR-AIR BOX TEMP.	RB-COM OUT PRESS.	LB-COM OUT PRESS.	LB-AIR BOX PRESS.	RB-AIR BOX PRESS.
1	45.4	42.7	193.9	89.4	139.5	121.7	120.6	125.4	175	175	179	176
2	47.0	43.9	197.5	222.3	128.7	122.3	121.4	126.0	173	173	177	175
3	46.6	45.1	199.8	140.5	124.9	124.1	121.8	126.2	179	180	183	180
4	43.1	42.0	73.2	71.9	91.2	92.5	92.0	95.4	23	24	39	101
5	41.4	41.3	89.6	63.3	99.5	102.5	100.1	105.8	38	39	65	102
6	43.4	42.8	125.8	*	116.4	119.8	115.5	124.8	73	74	110	111
7	50.9	48.9	175.1	*	117.8	118.8	115.4	119.5	131	132	136	135
8	50.8	49.3	207.2	64.0	126.7	126.7	123.3	128.3	176	176	180	177
9	47.7	44.5	209.6	60.5	126.0	126.2	122.4	127.1	189	189	192	192
10	53.1	47.6	202.3	41.5	127.6	128.5	124.2	129.5	166	166	171	172
11	36.3	34.7	68.9	66.8	92.3	95.8	93.8	99.2	25	26	46	45
12	40.0	37.5	98.1	103.7	99.1	100.3	98.8	103.3	52	52	71	69
13	42.7	40.0	131.6	140.2	130.5	105.9	105.1	107.8	88	88	99	99
14	47.4	43.3	181.2	*	116.9	111.4	113.3	113.3	145	145	142	140
15	43.3	40.2	113.1	*	118.5	126.0	120.7	132.7	57	58	107	106
16	46.4	43.4	133.6	102.9	129.9	118.0	112.4	120.8	86	86	104	104
17	49.9	46.2	174.1	100.4	117.6	118.4	114.5	119.1	133	133	137	135
18	54.6	49.4	218.0	191.9	130.5	131.8	126.8	132.0	186	187	190	188
19	44.0	42.1	53.1	*	87.6	85.4	87.7	89.4	4	5	11	13
20	29.0	29.4	37.7	*	51.3	53.5	51.7	54.1	3	4	19	18
21	34.1	34.2	43.8	*	86.3	87.6	86.8	86.9	4	5	17	16
22	35.4	34.7	44.8	*	83.9	84.7	83.9	86.3	4	5	17	16
23	35.9	34.8	45.5	44.6	84.7	85.6	84.6	85.7	4	5	17	17
24	36.6	34.7	46.1	44.5	84.1	84.8	84.0	86.4	4	5	17	17
25	36.9	35.5	72.9	72.2	92.0	94.5	93.1	96.7	31	32	52	50
26	39.0	38.4	119.8	118.3	116.6	122.2	117.7	125.8	72	73	123	121
27	38.8	38.5	31.0	*	80.4	80.8	80.5	80.1	2	3	13	13
28	39.1	38.1	32.5	*	81.6	81.5	81.0	81.1	1	2	11	11
29	39.8	39.6	32.8	*	70.5	73.1	72.0	72.3	1	2	11	12
30	70.7	70.4	35.1	*	94.7	97.1	95.2	98.3	31	33	53	47
31	35.9	35.7	68.2	66.4	92.6	95.9	93.5	95.5	24	25	46	43
32	33.1	31.5	76.0	71.9	94.0	96.1	94.7	95.7	34	35	56	51
33	33.5	31.5	78.7	74.9	93.8	96.0	94.6	99.2	36	37	57	54
34	34.5	32.2	78.1	74.8	94.5	96.6	95.1	96.6	36	37	57	54
35	34.4	31.7	79.9	76.0	94.7	96.7	95.3	99.1	37	38	58	54
36	35.8	33.4	121.8	117.8	119.9	126.1	122.2	133.8	77	79	130	127
37	36.9	34.1	123.7	118.8	120.0	126.1	121.9	132.4	77	79	125	124
38	31.6	28.7	74.8	71.6	94.4	95.8	94.8	97.3	36	38	57	54
39	31.8	28.7	75.7	72.4	94.6	96.0	95.0	98.8	36	38	57	55
40	31.6	28.8	74.9	72.1	94.6	95.9	95.0	97.6	36	38	57	55
41	31.8	29.0	75.5	73.2	94.9	96.2	95.2	98.9	37	38	57	55
42	32.6	30.5	115.4	111.5	118.7	126.2	121.0	127.5	73	75	124	122
43	33.2	31.0	116.5	113.8	119.0	126.9	121.4	129.2	74	76	124	122
44	33.5	31.3	115.8	113.7	119.5	127.5	122.0	129.0	75	76	123	121
45	33.9	31.3	115.8	112.9	118.2	126.6	120.7	128.5	75	75	117	116
46	29.1	29.4	68.1	66.0	92.1	93.8	92.2	92.1	30	31	51	50
47	35.0	33.5	79.2	76.5	96.3	96.9	95.6	98.2	36	37	57	54
48	35.6	33.4	80.1	77.2	95.9	97.2	96.1	100.4	36	38	57	55
49	36.8	35.3	122.5	119.1	118.1	125.0	120.4	126.8	76	77	123	123
50	35.5	34.2	113.5	108.3	118.2	127.1	121.5	127.2	63	65	115	114
51	36.9	34.8	120.5	117.6	119.7	128.2	123.2	130.3	71	73	122	121
52	37.9	35.8	121.7	119.3	119.9	128.3	123.2	131.1	72	73	121	120

ENGINE AIR SYSTEM TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RU #	RB-COM IN TEMP.	LB-COM IN TEMP.	RB-COM OUT TEMP.	LB-COM OUT TEMP.	RF-AIR BOX TEMP.	RR-AIR BOX TEMP.	LF-AIR BOX TEMP.	LR-AIR BOX TEMP.	RB-COM OUT PRESS.	LB-COM OUT PRESS.	LB-AIR BOX PRESS.	RB-AIR BOX PRESS.
53	38.4	35.5	121.2	117.9	119.4	127.6	122.8	129.1	71	73	121	120
54	38.3	35.4	122.0	119.7	119.4	128.0	122.8	130.4	72	74	121	120
55	36.7	35.6	114.5	109.5	116.6	124.4	119.3	125.0	62	64	115	114
56	38.6	36.5	122.8	120.3	120.3	127.9	123.1	129.3	72	74	122	121
57	39.0	36.6	125.0	121.8	121.0	128.4	123.8	131.0	73	75	123	122
58	39.3	37.6	124.0	121.4	120.2	128.2	123.0	128.8	73	74	123	121
59	39.9	38.0	125.3	123.1	119.8	128.0	122.8	129.5	74	77	121	120
60	40.2	38.2	125.7	121.5	118.7	126.8	121.7	128.9	73	74	118	117
61	38.8	37.3	122.9	120.0	119.8	126.9	122.5	130.1	72	72	122	121
62	39.4	37.6	125.5	121.7	121.0	128.2	124.0	133.2	72	74	122	122
63	39.6	37.9	125.5	122.1	120.6	127.6	123.4	131.4	72	73	122	121
64	39.9	38.1	124.9	121.2	120.0	127.6	122.9	130.9	73	74	122	121
65	40.0	38.6	126.4	123.0	120.5	128.2	123.6	133.3	72	73	121	121
66	40.1	37.8	126.5	121.7	120.6	127.8	123.6	132.4	72	74	123	122
67	40.4	38.3	126.1	123.4	120.8	128.1	123.8	132.5	73	73	122	121
68	40.9	38.6	126.7	123.5	120.7	128.0	123.7	131.1	72	74	122	121
69	26.4	26.6	35.7	34.9	52.7	54.9	53.1	52.3	2	4	19	19
70	33.5	31.5	109.4	106.1	115.7	124.2	118.8	124.2	63	65	116	114
71	36.8	33.3	119.0	117.2	120.3	127.9	123.3	128.7	74	76	124	121
72	37.2	35.0	119.6	118.2	118.3	126.8	121.5	128.4	73	73	117	115
73	37.6	34.9	119.2	118.7	118.6	127.4	121.7	128.2	74	75	119	117
74	38.7	35.3	119.5	119.1	117.5	126.3	120.8	128.0	73	75	116	115
75	38.4	35.5	119.4	119.3	117.9	126.6	120.8	129.2	73	74	116	114
76	39.3	36.1	119.9	118.6	118.2	126.6	121.1	128.2	73	76	117	114
77	39.5	36.8	120.1	119.7	117.9	126.9	121.2	128.6	73	74	116	114
78	40.3	37.3	120.5	119.3	117.9	126.9	121.0	129.4	73	74	116	114
79	40.5	36.6	120.5	119.2	119.0	127.5	121.9	128.5	74	75	118	116
80	38.8	36.1	119.6	119.1	117.4	126.4	120.7	128.0	74	74	115	114
81	39.2	35.7	120.4	119.2	117.8	126.7	120.8	129.1	72	74	116	114
82	40.7	37.3	126.4	123.7	113.2	119.9	114.7	118.7	85	86	104	104
83	30.3	30.0	38.8	37.5	81.2	82.1	81.6	81.0	2	4	14	14
84	30.5	30.4	37.5	36.9	81.8	81.6	81.4	80.8	2	3	12	13
85	30.5	30.4	37.5	36.7	81.7	81.7	81.4	80.8	1	3	11	13
86	36.0	35.8	113.6	108.5	118.5	125.0	120.4	127.2	62	63	114	113
87	38.4	37.1	121.2	118.9	119.7	126.3	121.4	129.2	73	74	120	118
88	39.4	37.6	122.4	119.5	117.7	124.9	119.5	127.6	75	77	116	115
89	39.2	36.9	120.7	118.9	118.3	125.6	120.2	128.1	72	73	116	115
90	39.8	37.1	121.4	119.9	118.1	125.2	119.8	127.9	76	77	115	115
91	39.4	36.8	121.5	119.9	115.8	123.7	117.7	127.8	77	79	115	113
92	38.2	36.4	124.5	121.3	119.6	126.2	121.5	129.8	76	78	123	121
93	38.9	38.1	124.1	121.5	118.1	125.4	120.2	127.4	76	77	118	117
94	39.2	38.2	126.0	122.6	118.1	125.3	120.1	127.9	79	81	119	118
95	39.4	38.4	125.4	123.6	116.3	123.7	118.1	127.9	80	81	117	116
96	39.8	38.5	125.1	121.6	118.6	125.8	120.4	128.7	75	77	118	117
97	38.0	36.4	123.2	119.6	117.9	124.5	119.2	126.9	76	78	117	116
98	39.7	37.9	125.8	123.1	117.3	124.4	118.9	128.6	79	80	117	116
99	40.5	38.8	126.4	124.3	117.0	124.5	118.7	129.2	80	80	116	116
100	40.6	38.7	125.2	123.1	117.1	124.4	118.7	129.3	80	82	115	116
101	36.0	34.8	120.6	118.9	116.6	123.6	117.6	126.6	77	79	113	111
102	37.4	35.6	122.1	120.1	115.9	122.9	117.2	126.4	79	79	110	109
103	38.3	36.9	133.7	132.6	111.5	112.5	110.3	111.1	95	98	100	100
104	21.1	18.3	100.9	96.0	114.8	122.0	116.6	121.6	76	78	121	119

ENGINE AIR SYSTEM TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	RB-CO IN TEMP.	LB-COM IN TEMP.	RB-CO OUT TEMP.	LB-COM OUT TEMP.	RF-AIR BOX TEMP.	RR-AIR BOX TEMP.	LF-AIR BOX TEMP.	LR-AIR BOX TEMP.	RB-COM OUT PRESS.	LB-COM OUT PRESS.	LB-AIR BOX PRESS.	RB-AIR BOX PRESS.
105	23.3	21.3	103.6	100.7	107.6	117.1	110.3	118.0	82	83	105	105
106	24.1	21.6	103.6	101.2	108.1	117.3	110.7	117.2	81	82	104	105
107	25.8	23.9	108.3	105.1	111.4	117.5	111.7	118.4	81	83	110	110
108	25.8	22.2	104.9	98.9	115.9	121.7	116.4	122.7	74	74	117	116
109	35.2	33.3	138.5	140.0	113.4	112.8	110.2	108.9	109	110	114	112
110	33.9	32.4	45.3	43.3	85.1	85.3	86.1	84.9	1	3	10	11
111	34.0	32.4	140.1	138.3	112.6	111.5	109.4	108.7	111	111	116	113
112	34.9	33.2	140.7	142.6	114.3	114.1	111.5	111.6	110	112	116	114
113	35.6	32.8	132.8	135.3	115.8	115.2	112.2	110.5	96	98	102	102
114	30.5	30.9	138.2	139.8	114.0	113.5	107.7	109.3	118	120	123	122
115	32.5	30.3	155.7	150.7	122.5	127.1	120.2	126.0	125	128	194	194
116	35.9	35.1	142.5	139.2	112.7	111.5	105.1	107.5	113	114	117	115
117	37.6	36.6	145.0	140.7	113.6	112.8	107.4	108.8	110	111	115	113
118	31.7	29.1	97.3	93.6	103.4	105.0	93.7	103.7	61	63	68	66
120	33.4	31.7	138.9	134.5	111.8	111.5	107.0	109.6	110	112	114	112
121	33.4	31.6	138.9	134.4	111.5	111.4	107.0	109.6	113	115	118	113
122	33.4	32.3	138.8	134.8	113.0	112.5	108.9	110.6	111	113	116	112
123	32.5	31.5	138.5	134.9	114.4	113.4	111.0	111.7	110	112	116	113
124	32.6	31.5	138.7	134.4	114.5	113.6	111.3	111.9	113	115	118	114
125	32.1	31.0	139.2	135.0	115.6	114.4	113.1	112.8	112	114	117	114
126	33.3	31.6	139.9	135.2	115.8	114.7	113.6	113.2	111	113	116	114
127	33.4	31.7	141.7	137.0	116.2	115.2	114.8	113.7	113	115	118	116
128	34.4	32.9	140.6	135.9	116.0	115.5	114.6	114.0	110	112	116	113
129	33.6	32.4	140.9	136.2	116.3	115.8	114.9	114.3	85	92	126	114
130	33.0	31.4	142.2	136.8	120.9	121.3	126.6	120.7	109	110	114	114
131	29.4	32.6	137.3	137.0	115.7	115.2	113.3	112.7	110	112	115	112
132	34.2	33.5	155.1	148.6	129.2	134.2	138.8	137.6	116	119	183	182
133	33.8	32.8	156.7	150.3	132.7	138.0	148.7	141.6	117	120	183	181
134	33.7	33.8	156.3	151.6	133.2	138.5	149.2	142.5	119	120	184	182
135	29.0	32.5	134.6	135.4	127.7	133.2	143.2	138.3	97	99	157	156
139	27.5	26.3	117.1	113.7	122.6	128.5	135.7	129.9	82	84	140	137
140	34.8	33.6	120.3	120.4	127.6	133.9	143.7	136.6	77	79	131	130
141	35.2	33.8	125.1	124.0	128.7	135.1	145.6	138.1	80	83	135	133
144	26.3	26.3	117.6	113.9	124.3	129.6	137.8	131.7	81	85	139	138
145	25.2	26.0	117.4	115.4	124.1	129.6	138.2	132.9	84	87	142	140
146	25.6	28.0	121.7	121.5	125.1	131.1	139.8	133.6	90	91	147	145
147	26.9	28.0	138.1	137.4	129.8	135.3	145.3	138.7	110	113	173	171
149	41.3	41.1	193.0	193.8	127.7	127.4	130.9	128.0	180	181	184	181
150	32.3	30.0	179.5	178.4	124.1	122.9	122.1	123.0	185	186	189	188
151	29.6	28.8	184.8	182.0	125.5	125.1	126.6	124.3	187	191	193	188
152	34.4	30.5	187.1	184.1	125.5	125.6	126.8	124.5	180	182	186	187
153	30.3	27.9	171.2	170.4	117.7	116.1	110.0	114.3	181	183	186	185
154	28.2	28.2	182.8	181.1	123.5	123.0	123.0	121.8	189	189	193	191
155	32.3	31.4	188.6	185.1	125.0	124.6	125.4	123.6	190	192	193	190
156	30.6	30.0	186.9	183.8	125.3	124.8	126.0	123.7	189	191	193	190
157	30.3	29.6	187.6	184.8	125.7	125.0	126.5	124.3	189	190	194	191
158	28.4	28.6	186.5	184.4	125.4	125.0	126.7	124.6	189	192	193	194
159	33.0	30.6	189.2	186.1	125.7	125.4	127.1	124.8	186	188	190	190
160	30.3	28.8	113.9	109.6	122.3	128.7	135.0	129.7	70	73	129	127
161	30.0	28.3	125.5	124.6	124.4	131.0	138.7	132.9	87	89	146	144
162	31.5	29.8	127.1	126.5	124.8	131.6	139.2	133.7	87	88	146	144
163	29.9	28.2	126.4	125.5	124.7	131.2	139.1	133.4	87	89	147	144

ENGINE AIR SYSTEM TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	RB-CO IN TEMP.	LB-COM IN TEMP.	RB-CO OUT TEMP.	LB-COM OUT TEMP.	RF-AIR BOX TEMP.	RR-AIR BOX TEMP.	LF-AIR BOX TEMP.	LR-AIR BOX TEMP.	RB-COM OUT PRESS.	LB-COM OUT PRESS.	LB-AIR BOX PRESS.	RB-AIR BOX PRESS.
164	30.9	29.3	127.3	126.3	124.8	131.4	139.5	133.9	88	90	147	145
165	36.1	34.1	125.6	123.0	123.8	130.2	137.5	131.7	76	79	134	132
166	37.0	34.7	127.1	124.0	124.4	130.6	138.4	132.6	77	79	134	132
167	38.4	38.2	148.4	144.2	130.8	135.9	146.0	139.3	99	100	160	157
168	38.5	36.8	148.1	143.6	131.0	136.2	146.1	139.4	98	100	159	157
169	40.9	37.5	148.9	144.1	131.1	135.8	146.1	139.2	99	100	159	156
170	42.2	37.6	172.1	164.7	137.5	143.5	153.8	146.5	124	126	192	188
171	40.5	37.5	172.5	165.2	137.8	144.2	154.7	147.2	126	127	194	190
172	41.3	39.0	157.9	156.4	120.8	121.1	118.1	116.8	124	127	130	128
173	41.5	39.8	159.6	158.1	119.8	119.8	116.6	116.0	125	127	130	129
174	34.7	33.4	127.0	126.4	125.0	131.4	138.4	132.9	80	83	137	135
175	35.3	36.2	150.8	151.5	132.4	137.6	147.4	142.0	110	112	173	171
176	35.4	35.4	152.1	151.5	132.5	137.9	147.8	142.7	111	113	175	171
177	37.2	36.0	153.2	152.2	133.0	138.3	148.3	143.3	111	112	173	170
178	36.8	34.8	144.7	141.1	130.9	136.4	143.7	138.2	98	101	160	158
179	38.1	35.8	147.5	144.5	131.5	137.1	145.4	139.4	102	104	163	161
180	38.1	35.7	147.9	145.2	131.6	136.7	145.7	139.7	101	105	163	161
181	35.5	36.3	147.9	147.4	131.6	137.2	146.1	140.0	105	107	167	164
182	36.9	36.4	149.7	148.2	132.1	137.7	146.6	140.7	105	107	168	165
183	35.9	35.8	150.0	149.2	132.4	137.6	147.2	141.2	108	110	171	168
184	36.0	36.4	150.4	151.2	132.5	137.7	147.4	141.8	108	111	170	168
185	35.6	37.0	150.8	151.9	132.8	137.9	147.8	142.7	110	113	172	169
186	36.4	36.4	151.2	151.0	132.9	137.7	148.0	143.1	108	111	171	169
187	37.2	37.4	152.2	152.2	133.0	137.9	148.1	143.3	109	110	171	169
188	34.4	35.2	150.9	150.2	133.0	137.7	148.1	143.3	110	112	173	170
189	38.5	36.8	146.8	143.7	131.9	136.9	146.4	140.7	99	101	159	158
190	33.5	32.5	142.2	138.2	128.4	133.5	139.8	135.1	100	101	162	161
191	33.9	34.5	146.8	145.2	131.9	136.7	145.1	139.4	105	108	168	166
192	34.2	35.0	147.7	145.8	132.1	137.4	145.8	140.4	106	107	167	166
193	35.8	34.4	151.1	147.8	133.0	137.4	147.0	141.4	107	109	170	168
194	37.5	36.7	151.9	150.2	133.3	138.0	147.6	142.0	107	110	170	168
195	35.0	35.3	152.5	152.2	133.6	138.5	148.5	143.1	111	114	176	173
196	36.5	37.1	153.2	152.9	134.1	138.7	148.9	144.0	111	114	176	172
197	34.1	34.2	149.7	147.8	133.6	138.3	148.0	142.3	107	108	169	167
198	29.3	27.0	44.0	40.7	87.0	86.7	90.6	87.1	1	4	11	13
199	27.6	25.9	127.5	120.6	126.1	130.1	135.2	130.8	90	92	152	151
200	31.4	28.5	140.3	135.5	130.3	134.3	142.6	135.8	103	106	166	164
201	29.4	27.0	142.6	137.0	131.2	135.8	145.3	138.3	106	109	170	167
202	29.6	27.4	143.9	138.3	131.5	135.9	145.5	138.5	106	108	171	168
203	30.4	28.4	145.2	141.6	131.8	136.6	146.2	139.5	108	110	173	170
204	28.6	27.5	144.8	141.1	131.9	136.9	146.2	139.3	110	112	175	172
205	31.9	28.5	147.2	144.2	131.8	136.8	146.7	139.9	110	111	174	172
206	27.6	28.5	145.8	144.0	131.9	137.0	146.7	140.0	112	115	177	174
207	32.0	29.7	149.7	147.5	132.5	137.6	147.7	141.3	115	116	180	176
208	29.9	28.1	148.6	146.6	132.6	137.7	147.8	142.1	115	118	181	177

ENGINE AIR SYSTEM TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	RB-CO IN TEMP.	LB-COM IN TEMP.	RB-CO OUT TEMP.	LB-COM OUT TEMP.	RF-AIR BOX TEMP.	RR-AIR BOX TEMP.	LF-AIR BOX TEMP.	LR-AIR BOX TEMP.	RB-COM OUT PRESS.	LB-COM OUT PRESS.	LB-AIR BOX PRESS.	RB-AIR BOX PRESS.
209	32.2	29.3	144.6	140.3	131.8	136.6	146.6	139.5	104	105	167	165
210	32.5	29.6	141.5	137.1	130.1	134.4	142.1	135.9	102	104	165	164
211	29.8	28.9	141.3	137.6	131.1	135.0	143.3	136.8	103	106	167	165
212	29.0	27.5	142.0	136.7	131.3	135.0	144.4	137.6	105	107	169	167
213	31.0	30.0	140.8	138.9	131.7	135.7	144.6	137.8	102	105	166	166
214	33.2	30.2	143.9	141.2	131.7	135.9	145.2	138.3	105	109	169	168
215	33.4	30.1	144.7	142.0	132.0	136.0	145.6	138.9	105	107	169	168
216	30.2	28.3	145.2	141.0	131.7	136.0	145.8	139.1	108	109	172	170
217	32.0	30.6	145.6	143.3	132.3	136.6	146.3	139.2	107	109	171	170
218	30.5	28.9	140.1	134.2	130.9	135.3	144.1	137.2	102	104	155	162
219	30.0	29.7	139.8	133.6	130.7	135.4	144.3	137.0	101	104	165	163
221	34.7	33.3	141.4	137.9	129.5	134.7	142.7	135.6	98	101	161	159
222	35.0	33.8	142.0	139.6	129.7	134.7	143.5	136.1	98	102	161	160
223	33.2	33.0	132.3	127.6	122.9	127.8	130.5	128.8	90	92	152	151
224	27.0	26.1	125.5	120.9	123.6	128.6	132.7	129.0	92	94	155	154
225	27.9	26.3	129.2	124.6	127.1	131.6	137.6	132.4	95	97	159	156
226	23.2	23.6	134.4	128.5	129.7	134.0	142.2	135.9	106	110	171	168
227	22.6	22.5	133.5	128.3	129.8	133.8	142.4	135.6	107	109	170	168
228	23.7	23.6	135.1	128.3	129.8	134.3	143.3	136.3	104	106	168	166
229	25.6	23.2	137.4	131.1	130.5	134.8	143.8	136.7	107	110	171	169
230	25.3	23.6	139.5	134.4	130.3	135.0	144.4	137.6	112	114	176	174
231	25.0	24.7	139.0	134.8	130.6	135.0	144.7	137.6	111	113	175	173
232	23.0	22.9	140.4	135.5	131.5	135.4	145.0	138.0	114	116	180	177
233	24.8	25.1	140.7	137.1	131.2	135.6	145.3	138.5	114	116	180	177
234	23.8	23.9	140.7	137.2	131.6	135.9	145.4	138.6	115	118	180	178
235	24.9	24.8	141.1	137.6	131.8	136.0	145.4	138.7	116	116	180	177
236	24.8	25.3	133.2	129.4	127.0	131.8	138.7	133.3	105	106	168	168
237	24.5	25.1	134.3	130.2	128.2	132.8	140.3	134.3	105	107	168	168
238	28.6	27.4	135.5	131.1	130.1	134.2	142.9	136.4	98	100	161	162
239	28.1	27.6	138.3	133.9	130.6	134.2	143.5	136.9	105	107	168	167
240	27.5	27.1	139.2	136.0	130.8	135.0	144.0	137.3	106	109	171	170
241	26.9	27.3	139.6	136.2	130.9	135.1	144.3	137.5	107	109	171	170
242	27.8	27.7	142.0	138.0	130.9	135.5	144.7	138.2	110	112	174	173
243	28.8	28.6	142.3	140.5	131.6	135.9	145.3	138.6	110	112	174	173
244	27.6	27.7	139.2	135.4	131.4	135.1	144.8	138.0	106	109	168	168
245	27.1	26.6	138.8	133.9	130.5	134.9	144.3	137.9	107	109	168	168
246	27.6	27.1	160.6	160.4	121.3	117.7	108.2	112.7	161	168	169	166
247	31.8	31.5	175.4	173.0	124.9	122.8	117.9	118.3	171	173	175	172
248	33.8	34.4	182.3	181.8	128.2	125.7	124.5	122.4	172	176	178	176
249	35.9	35.5	184.3	182.7	128.4	126.1	125.0	122.8	173	178	178	177
250	36.0	35.7	186.0	183.2	128.8	126.2	125.7	123.4	175	177	180	178
251	34.6	34.8	184.9	183.4	128.4	125.7	125.8	123.4	177	176	181	179
252	37.5	37.5	187.2	187.6	129.6	126.5	126.4	124.1	177	180	181	180
253	35.7	36.6	187.8	186.0	129.7	126.6	126.5	124.0	176	178	181	179
254	33.2	31.8	165.1	164.2	120.0	117.3	108.1	113.4	158	162	165	162
255	34.1	33.9	181.4	180.2	124.2	122.5	119.1	119.6	172	175	177	175
256	34.9	35.7	183.4	181.9	125.2	123.8	121.3	120.6	174	177	179	176
257	34.7	35.6	185.2	184.1	126.6	125.8	124.1	122.4	175	175	179	177
258	36.4	35.1	186.6	184.6	126.1	125.9	124.7	123.0	175	176	180	178
259	40.1	40.3	190.5	190.6	127.5	126.4	126.2	124.1	177	174	180	177
260	37.7	36.0	189.0	187.6	127.5	126.9	126.4	124.1	176	177	180	179
261	39.7	40.5	190.8	190.0	128.1	127.3	126.7	124.4	174	176	179	177

ENGINE AIR SYSTEM TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	RB-CO IN TEMP.	LB-COM IN TEMP.	RB-CO OUT TEMP.	LB-COM OUT TEMP.	RF-AIR BOX TEMP.	RR-AIR BOX TEMP.	LF-AIR BOX TEMP.	LR-AIR BOX TEMP.	RB-COM OUT PRESS.	LB-COM OUT PRESS.	LB-AIR BOX PRESS.	RB-AIR BOX PRESS.
262	39.4	38.7	189.1	188.2	127.7	126.9	126.9	124.5	175	176	180	178
263	42.0	41.6	191.8	192.1	128.1	127.6	127.1	125.0	173	177	178	177
264	31.2	29.3	163.7	163.1	119.4	117.1	107.8	112.9	162	164	167	165
265	32.2	29.5	181.2	178.7	124.8	123.3	120.7	120.1	178	180	183	180
266	36.6	36.1	171.8	171.6	121.4	120.3	111.3	115.6	162	161	166	163
267	36.5	36.8	165.5	165.2	122.6	119.8	107.8	113.7	157	156	162	161
268	40.0	40.0	187.0	187.2	126.9	126.1	122.8	122.3	172	175	177	174
269	35.2	35.2	130.1	125.4	122.6	127.7	131.9	127.9	86	88	148	148
270	35.6	35.8	143.0	141.0	129.6	135.2	142.3	136.3	99	101	162	161
271	36.6	37.1	146.2	143.0	131.5	136.8	145.8	138.9	100	102	163	162
272	37.5	37.6	146.8	144.6	132.0	137.0	146.4	139.6	101	103	164	163
273	37.2	36.8	149.3	146.8	132.3	137.5	147.1	140.0	103	106	166	165
274	37.2	36.5	158.4	158.0	119.1	118.5	106.5	111.9	152	156	158	156
275	41.1	41.2	190.3	189.9	128.1	125.8	124.3	122.9	172	174	177	175
276	40.8	39.4	154.9	150.4	132.9	138.2	147.2	140.6	105	106	168	168
277	29.6	30.0	159.0	160.0	120.8	118.0	106.3	112.1	160	163	166	163
278	36.6	35.4	182.0	182.8	124.7	125.0	120.8	120.8	171	175	177	175
279	34.5	34.8	130.7	125.4	126.3	131.8	136.0	133.0	88	90	150	150
280	34.7	34.7	143.1	141.7	130.8	137.0	144.7	138.6	101	102	163	163
281	36.1	35.3	143.1	141.5	131.7	137.6	146.0	139.6	98	101	162	161
282	34.4	33.6	141.6	139.5	131.4	137.0	145.2	139.3	100	101	162	161
283	32.7	33.4	143.3	142.4	134.1	139.8	149.8	143.0	105	107	167	166
284	36.0	35.9	142.0	139.6	133.0	138.4	148.5	141.7	98	100	158	158
285	32.8	32.9	132.7	127.4	130.2	135.4	142.6	137.2	90	92	152	150
286	33.3	32.6	141.2	138.4	132.7	137.7	146.7	140.6	103	103	164	162
287	33.4	35.1	139.6	138.3	133.4	138.4	148.4	141.5	98	99	158	157
288	34.2	34.7	141.1	139.5	133.7	138.4	148.6	142.0	97	99	157	158
289	34.1	34.4	144.2	142.7	134.1	139.3	149.4	142.6	107	107	167	164
290	32.8	33.9	143.5	142.7	133.9	139.2	149.6	142.6	107	108	168	164
291	35.4	35.1	143.3	142.7	133.8	138.8	149.6	142.7	105	106	167	159
292	35.1	34.7	142.8	141.3	133.7	138.8	149.4	142.6	101	104	161	159
293	35.3	36.5	145.4	147.3	134.9	140.5	150.5	143.7	105	107	167	164
294	35.6	34.1	146.6	145.7	135.0	140.5	150.7	143.9	106	107	167	164
295	35.5	35.1	145.0	145.0	135.1	140.1	150.8	143.9	103	106	164	162
296	35.8	34.8	144.7	144.8	134.9	139.8	150.5	143.6	104	105	164	162
297	28.6	28.2	129.4	125.1	128.6	132.7	137.8	133.3	93	96	156	154
298	30.3	29.9	137.2	136.7	131.2	135.7	142.9	137.1	103	104	167	164
299	31.3	31.5	140.4	137.1	133.7	139.2	148.8	141.9	105	106	167	163
300	31.5	31.9	139.7	137.7	133.7	138.7	148.5	141.7	103	106	164	163
301	32.2	31.0	141.3	138.6	133.8	139.0	148.8	141.8	106	107	167	162
302	31.2	30.6	141.4	137.8	134.6	138.9	149.2	142.3	107	109	168	165
303	30.5	29.5	140.1	135.7	134.3	138.7	149.1	141.9	108	109	169	164
304	31.6	31.1	139.9	135.3	134.5	139.3	149.2	142.4	105	106	166	161
305	32.0	31.9	140.8	138.7	134.6	139.3	149.2	142.5	105	109	167	164
306	31.6	31.9	141.0	137.5	134.7	139.2	149.4	142.9	104	106	165	163
307	30.5	30.9	140.1	136.2	134.7	138.9	149.3	142.6	105	107	167	164
308	31.3	31.4	143.1	140.5	134.4	139.2	149.5	143.1	110	112	172	169
309	30.7	30.1	143.3	141.2	134.9	139.5	150.0	143.6	111	113	173	170
310	32.2	30.5	141.8	139.9	134.3	138.9	149.7	143.1	105	107	167	165
311	31.9	31.0	143.9	141.3	134.6	139.6	150.0	143.6	104	107	163	166
312	31.9	31.1	142.5	139.0	134.5	140.0	149.8	143.3	100	103	161	164
313	32.7	32.2	140.3	138.3	134.4	139.6	149.6	143.3	106	110	168	163

ENGINE AIR SYSTEM TEMPERATURES (DEG. C) AND PRESSURES (kPa)

RUN #	RB-CO IN TEMP.	LB-COM IN TEMP.	RB-CO OUT TEMP.	LB-COM OUT TEMP.	RF-AIR BOX TEMP.	RR-AIR BOX TEMP.	LF-AIR BOX TEMP.	LR-AIR BOX TEMP.	RB-COM OUT PRESS.	LB-COM OUT PRESS.	LB-AIR BOX PRESS.	RB-AIR BOX PRESS.
314	32.3	32.6	141.6	138.8	134.4	139.7	149.4	143.3	101	102	160	163
315	32.3	32.0	143.9	141.2	134.4	139.6	149.8	143.6	112	112	173	168
316	27.3	27.1	122.9	118.5	125.6	130.0	134.2	130.9	90	93	154	152
317	26.0	28.0	132.3	132.3	131.2	136.1	142.9	137.5	104	106	168	165
318	26.8	29.1	135.2	135.8	133.6	138.7	147.4	140.9	106	109	170	167
319	28.1	28.1	136.2	135.1	134.0	138.1	147.6	141.5	105	107	168	166
320	29.5	29.1	137.1	136.4	133.8	139.0	148.5	142.0	108	110	171	166
321	29.2	29.2	139.2	137.6	134.6	139.7	149.1	142.8	98	101	160	164
322	28.5	28.9	138.1	139.1	134.0	139.4	148.5	142.7	109	111	173	171
323	27.3	27.1	138.9	138.7	134.5	139.9	149.4	143.1	111	113	175	172
324	28.0	29.6	136.6	136.7	133.8	139.2	148.5	142.7	107	110	167	166
325	26.1	27.6	137.2	137.5	133.7	140.0	148.6	142.7	108	111	171	168
326	27.0	28.6	139.3	141.7	134.6	140.0	149.8	144.3	113	115	177	172
327	27.6	28.4	141.3	142.8	135.2	140.3	150.6	145.3	116	118	179	175
328	29.3	29.3	141.4	143.2	135.4	140.2	150.7	145.1	113	114	177	173
329	27.5	29.5	141.1	144.1	135.5	140.8	150.9	145.4	113	115	177	174
330	36.4	34.5	139.8	140.9	133.6	139.0	148.1	141.0	99	100	161	156
331	37.5	34.3	140.5	141.3	134.1	138.9	148.7	141.4	99	100	160	156
332	36.3	33.6	106.4	102.9	110.8	109.6	114.4	109.0	60	62	79	82
333	40.0	36.5	105.5	102.8	110.2	108.5	111.8	107.6	61	63	80	80
334	34.8	33.3	67.6	64.2	96.2	96.7	100.7	97.8	15	17	28	31
335	35.3	33.5	63.4	60.8	93.8	93.9	95.9	95.0	15	17	29	31
336	34.4	32.9	57.7	55.9	89.0	89.6	88.3	90.3	15	17	29	31
337	33.4	32.0	56.7	54.8	88.5	89.1	87.6	89.7	15	17	30	31
338	34.4	33.6	52.3	51.1	87.5	86.2	82.9	87.1	10	12	20	22
339	35.5	33.4	52.4	50.5	87.6	86.0	82.2	86.5	9	12	19	22
340	35.2	33.5	51.8	50.6	87.4	85.9	81.8	85.8	9	12	20	22

ENGINE EXHAUST TEMPERATURES (DEG. C)

RUN #	CYL. #1L	CYL. #1R	CYL. #2L	CYL. #2R	CYL. #3L	CYL. #3R	CYL.#4L (TEST- CYL.)	CYL. #4R	RB-TUR IN TEMP.	RB-TUR OUT TEMP.	LB-TUR IN TEMP.	LB-TUR OUT TEMP.
1	630.0	565.2	628.0	575.8	645.4	511.3	643.7	570.4	554.6	414.6	635.8	488.4
2	635.1	572.4	635.4	582.3	647.7	515.6	647.6	572.8	559.8	419.3	641.1	493.5
3	595.0	634.0	602.5	620.0	611.3	578.1	618.5	586.7	600.0	451.2	607.4	461.7
4	312.7	317.0	321.9	320.8	329.4	309.2	330.7	301.4	320.3	284.9	329.7	293.4
5	307.5	333.4	319.8	327.8	341.1	309.1	346.1	309.0	319.9	265.8	331.9	278.6
6	379.6	406.5	383.4	395.2	405.6	391.8	406.2	373.9	388.3	302.8	394.9	310.9
7	574.4	574.0	563.3	572.5	579.0	569.6	588.2	544.1	562.9	439.0	573.9	453.3
8	603.8	645.2	609.9	628.3	621.7	597.0	632.7	602.5	615.2	465.5	618.8	472.7
9	602.3	649.7	605.4	628.6	626.8	629.6	631.6	605.2	623.0	466.2	615.2	463.9
10	667.2	699.6	672.2	672.8	688.3	692.1	695.1	659.7	682.5	527.1	682.7	552.5
11	272.0	292.0	281.4	293.8	297.2	274.5	314.4	267.4	282.7	243.2	293.6	254.4
12	364.2	380.8	380.4	378.3	399.9	374.0	408.9	372.1	383.1	318.8	393.4	331.6
13	450.4	470.2	473.3	467.5	490.1	460.2	491.1	462.1	476.1	384.3	485.1	395.8
14	576.8	588.7	614.4	586.7	612.2	580.1	616.5	563.9	595.9	465.0	618.0	491.4
15	329.3	336.5	321.8	332.3	339.9	336.3	355.8	318.8	328.0	252.5	337.9	262.7
16	445.0	479.9	446.8	460.5	466.0	465.3	484.5	446.2	458.7	366.2	460.1	370.4
17	556.5	598.0	554.1	578.8	569.5	574.4	584.1	546.7	571.8	446.7	566.2	446.4
18	609.7	660.0	609.4	633.9	632.4	651.0	636.1	619.1	640.5	484.0	624.2	473.7
19	256.0	271.7	272.8	270.9	264.4	257.0	279.9	259.1	276.1	259.6	281.1	263.6
20	156.2	168.9	165.7	170.6	174.2	157.3	187.0	151.8	154.7	133.9	164.8	142.8
21	203.3	203.8	205.5	211.0	208.1	196.4	108.1	196.5	199.7	180.0	171.3	161.0
22	177.4	185.4	182.3	186.2	191.1	172.9	196.3	171.7	178.3	166.6	187.6	174.8
23	188.7	194.8	194.8	197.2	198.8	183.5	153.8	182.9	187.6	178.1	179.8	166.1
24	179.2	185.3	182.2	185.6	189.3	173.8	195.9	172.6	177.9	165.7	187.4	175.0
25	327.8	326.5	332.9	327.9	346.0	319.0	331.4	310.6	314.0	255.4	324.7	267.8
26	357.0	377.9	358.3	371.1	381.2	374.5	358.3	353.3	362.7	275.2	360.5	275.8
27	189.8	191.4	189.1	197.4	190.4	165.6	100.5	176.9	178.8	165.9	155.3	145.2
28	169.8	177.1	180.0	192.5	173.4	163.9	101.3	160.2	172.5	164.0	148.6	142.9
29	166.2	164.3	174.6	178.6	168.1	150.0	89.9	152.7	158.0	142.8	137.3	125.6
30	318.6	332.9	319.2	319.1	325.3	316.8	230.4	305.0	318.2	279.0	282.8	242.8
31	310.6	312.1	315.7	314.3	318.0	308.7	172.3	295.6	306.8	265.9	264.6	225.0
32	349.6	339.4	342.8	341.7	343.5	332.5	207.5	323.1	337.2	293.0	296.9	250.8
33	328.8	328.7	336.2	331.5	337.1	326.8	295.5	317.2	331.8	286.2	323.3	272.8
34	351.0	342.1	345.7	343.7	345.6	335.0	222.9	327.5	342.1	296.6	307.9	261.1
35	337.7	338.0	341.6	342.3	342.9	331.8	272.8	324.6	340.2	293.2	322.3	273.4
36	371.9	378.2	362.4	365.4	386.0	381.2	316.3	357.2	369.2	283.7	354.4	265.3
37	370.6	377.8	365.9	363.5	387.8	383.4	352.0	360.5	370.6	283.4	367.8	279.3
38	358.7	332.7	347.2	344.6	342.3	332.1	228.3	321.4	339.8	295.8	310.7	261.9
39	351.3	328.9	345.3	338.8	340.2	329.3	253.1	318.9	337.2	291.9	318.4	270.2
40	355.8	329.4	346.3	344.8	340.9	330.7	231.8	319.4	338.4	294.1	312.1	264.7
41	349.9	327.5	344.6	340.7	338.7	330.1	254.5	316.3	336.7	291.1	318.6	271.7
42	373.8	373.3	372.2	316.5	394.9	378.8	287.6	370.6	356.5	274.6	348.9	262.1
43	374.2	372.8	375.9	314.9	396.0	375.4	310.0	370.9	355.8	272.8	358.2	272.7
44	381.3	375.4	377.7	319.8	398.0	382.4	296.2	371.9	359.5	277.4	355.9	269.8
45	386.0	378.9	383.6	318.6	404.3	386.6	316.2	377.5	362.2	279.9	366.5	282.2
46	367.4	349.5	341.7	349.5	349.3	333.9	150.2	325.9	339.0	292.6	275.2	236.2
47	353.4	343.7	350.8	347.1	350.6	336.1	242.3	329.3	347.0	302.7	317.2	268.5
48	345.8	336.8	347.8	341.9	349.5	333.3	261.4	327.8	344.2	297.9	325.0	278.7
49	382.7	390.4	379.7	374.7	398.4	384.3	313.7	371.6	377.4	289.7	360.9	272.5
50	402.4	391.6	378.3	304.8	412.5	379.5	192.9	384.6	358.8	278.0	326.9	252.2
51	395.5	380.8	390.3	301.1	408.6	369.7	315.3	376.0	353.1	271.2	369.3	282.9
52	397.5	379.8	393.6	302.5	408.4	370.2	324.0	377.1	353.2	271.3	375.6	291.4

ENGINE EXHAUST TEMPERATURES (DEG. C)

RUN #	CYL. #1L	CYL. #1R	CYL. #2L	CYL. #2R	CYL. #3L	CYL. #3R	CYL. #4L (TEST- CYL.)	CYL. #4R	RB-TUR IN TEMP.	RB-TUR OUT TEMP.	LB-TUR IN TEMP.	LB-TUR OUT TEMP.
53	400.9	384.7	393.5	303.3	410.6	372.2	301.1	378.5	354.9	273.5	368.6	283.2
54	401.9	382.4	397.0	302.5	411.0	372.8	326.1	378.5	354.5	272.2	378.1	292.9
55	407.9	393.5	384.4	324.5	415.4	375.9	192.5	383.0	359.4	276.1	324.1	248.7
56	400.2	384.6	388.5	330.6	409.0	373.6	308.2	379.5	362.6	279.0	365.5	278.5
57	401.8	385.1	390.9	337.1	411.3	373.3	325.9	380.0	365.5	280.3	374.4	287.9
58	410.3	387.0	391.7	342.2	414.2	377.5	300.4	382.9	369.8	285.4	368.5	282.0
59	412.7	389.3	396.3	340.9	417.4	380.1	328.0	384.1	370.5	285.7	379.8	294.0
60	416.6	392.9	400.5	345.2	420.8	383.5	338.5	387.7	373.6	289.8	385.7	301.3
61	384.2	374.5	375.4	383.5	398.0	369.0	301.6	364.6	371.5	286.8	355.6	269.1
62	383.9	373.9	380.5	382.6	399.8	369.2	322.7	364.7	371.8	285.8	365.9	281.2
63	384.8	374.5	381.2	382.0	397.6	370.2	317.0	366.8	372.8	286.6	364.6	280.9
64	382.1	378.2	378.7	383.2	399.6	372.8	311.0	367.3	374.6	289.8	362.4	276.2
65	381.9	376.6	382.0	384.1	401.3	372.8	325.5	368.1	375.1	289.0	368.9	284.8
66	380.8	378.2	378.6	383.5	401.8	374.0	317.6	367.0	374.8	289.6	365.6	280.4
67	379.8	375.9	381.6	383.7	401.8	373.8	324.7	365.3	375.0	288.7	368.8	284.9
68	380.9	376.3	381.8	383.8	402.3	374.1	319.4	367.1	375.2	289.1	367.6	284.1
69	207.7	155.1	192.0	162.4	205.0	183.5	68.0	189.1	168.3	146.2	145.3	125.4
70	407.9	387.4	381.8	298.0	422.4	374.6	191.2	382.2	350.7	269.2	325.3	248.5
71	399.9	385.0	393.2	302.3	410.1	377.4	317.4	379.3	355.8	273.7	371.1	281.7
72	403.4	390.2	403.9	303.7	421.6	379.0	331.5	384.3	358.8	277.8	384.5	301.2
73	403.4	391.0	400.8	305.4	419.7	383.5	326.6	385.9	361.1	279.6	380.1	291.7
74	403.6	395.0	401.8	306.5	423.9	384.7	338.8	387.4	362.8	281.3	386.6	303.2
75	404.3	394.6	401.5	306.5	422.9	385.9	328.6	388.1	363.1	281.7	383.3	301.1
76	403.5	394.4	399.2	307.8	421.4	387.7	332.8	388.9	364.4	282.5	382.5	295.5
77	403.9	395.5	401.2	308.5	425.0	387.7	339.4	390.6	365.3	283.2	386.3	302.7
78	404.4	396.2	402.0	309.2	424.7	388.7	331.8	389.7	365.5	283.8	384.9	302.2
79	403.0	395.2	397.8	308.6	420.0	388.6	324.3	388.4	365.1	283.0	377.4	288.9
80	403.7	397.7	401.3	309.8	424.6	388.7	339.3	390.0	366.2	284.5	386.5	303.0
81	403.1	397.9	400.1	310.7	424.9	389.2	329.8	390.7	366.8	284.8	383.5	301.2
82	483.8	459.0	466.0	466.4	490.2	445.3	347.7	444.4	452.8	362.4	427.9	336.8
83	198.6	191.2	198.8	174.3	195.6	179.5	90.7	183.0	180.8	171.1	160.3	151.0
84	188.3	185.7	194.4	185.0	187.5	166.1	91.4	170.1	175.0	165.9	155.2	147.5
85	187.5	183.5	192.8	184.7	186.0	166.5	91.0	169.2	174.5	165.5	154.3	146.9
86	374.3	383.2	354.5	378.9	391.4	382.8	188.0	362.9	374.8	291.8	309.2	236.6
87	367.2	378.4	363.7	374.4	389.8	375.3	353.8	360.7	372.4	288.0	366.0	283.0
88	370.1	382.6	367.7	376.7	392.5	377.3	383.2	362.4	374.4	291.3	379.3	295.9
89	372.5	383.7	368.6	379.1	393.9	379.4	342.5	364.5	376.2	293.1	368.8	290.3
90	371.7	382.9	367.6	377.9	393.5	378.9	364.5	364.1	375.6	292.5	374.5	292.3
91	370.8	384.5	372.0	377.3	394.5	378.8	450.1	365.3	375.9	293.2	402.5	315.8
92	377.0	385.4	370.5	382.9	396.1	382.7	355.9	366.1	378.4	291.2	371.4	285.4
93	379.7	388.6	373.5	385.1	400.3	386.4	368.1	370.9	383.0	297.7	379.5	295.8
94	379.3	388.4	374.6	387.0	400.6	386.3	388.2	369.6	382.8	297.5	385.2	299.5
95	379.7	387.9	377.9	385.6	401.7	387.0	466.9	371.3	382.9	297.9	411.4	320.9
96	382.3	389.3	375.5	385.1	403.6	388.3	361.5	371.9	383.3	298.1	379.7	296.2
97	382.8	393.7	377.1	388.0	401.2	390.7	361.2	375.5	386.5	301.6	377.4	293.6
98	380.4	390.7	377.4	387.5	401.0	388.0	426.8	373.9	384.2	299.2	398.2	308.3
99	381.1	392.0	379.5	385.7	400.6	388.7	451.2	375.4	385.1	300.4	406.3	315.0
100	379.2	390.7	377.5	385.4	401.4	388.5	440.8	374.8	384.8	300.1	402.2	311.1
101	383.7	400.7	392.0	396.0	408.0	398.1	367.0	385.1	395.1	309.9	386.9	304.4
102	383.1	401.5	395.7	395.9	410.1	401.9	390.8	386.6	396.7	312.1	396.2	312.2
103	531.7	551.9	524.5	548.8	548.0	538.9	421.3	511.8	533.5	439.3	489.7	401.2
104	398.2	410.3	374.5	306.1	412.5	402.3	191.4	390.0	369.2	285.4	325.1	248.2

ENGINE EXHAUST TEMPERATURES (DEG. C)

RUN #	CYL. #1L	CYL. #1R	CYL. #2L	CYL. #2R	CYL. #3L	CYL. #3R	CYL.#4L (TEST- CYL.)	CYL. #4R	RB-TUR IN TEMP.	RB-TUR OUT TEMP.	LB-TUR IN TEMP.	LB-TUR OUT TEMP.
105	415.8	429.7	413.8	314.3	438.8	418.5	366.4	413.2	385.7	306.3	403.4	324.0
106	414.3	428.8	413.5	313.6	439.2	417.3	367.0	410.6	384.3	303.7	402.9	321.4
107	381.2	399.8	380.5	389.2	397.9	393.3	374.1	377.8	386.7	304.3	380.3	299.4
108	378.9	395.3	361.4	390.0	394.5	393.9	191.6	376.7	388.5	303.6	316.4	244.2
109	566.4	589.5	532.8	580.6	565.3	560.7	360.7	535.8	561.6	458.7	471.0	386.4
110	185.4	192.8	191.5	202.6	185.5	177.3	114.3	183.3	214.5	226.2	185.1	190.7
111	571.1	596.3	537.0	591.1	569.3	566.9	362.4	538.8	565.6	460.2	470.8	383.5
112	572.5	595.1	539.3	588.7	568.1	566.1	361.0	539.9	567.9	459.7	477.4	389.0
113	623.8	629.4	558.1	623.4	609.7	598.8	271.9	570.9	600.0	491.3	460.8	392.0
114	567.8	600.0	532.5	579.4	562.2	567.9	338.6	537.6	567.6	457.8	464.7	375.7
115	509.0	539.9	483.2	519.9	514.2	518.4	320.4	488.4	508.6	408.6	432.5	342.4
116	572.1	608.5	546.6	592.5	574.7	571.0	339.0	545.8	574.1	471.2	468.4	383.6
117	577.6	608.5	530.5	591.3	577.4	572.0	339.6	547.8	575.3	469.3	474.6	389.9
118	505.5	520.9	482.7	503.7	513.9	499.4	347.6	473.8	494.8	430.0	428.7	377.3
120	536.2	569.7	524.7	560.7	551.9	541.0	393.2	521.9	545.0	442.1	478.0	391.1
121	534.3	570.0	524.0	558.9	551.0	539.8	398.4	519.6	543.6	441.1	478.9	391.4
122	535.5	569.1	525.4	560.0	551.7	541.9	394.3	520.6	545.2	441.9	477.9	391.1
123	536.9	570.0	526.1	563.5	553.2	543.3	394.0	520.8	545.6	442.6	479.3	392.4
124	535.1	569.4	525.7	560.9	553.9	542.1	396.4	520.3	544.8	441.7	479.9	392.2
125	535.5	571.0	526.1	564.4	551.0	543.5	396.0	520.5	545.9	442.2	479.6	392.0
126	536.0	572.3	526.7	563.6	551.3	544.3	397.8	521.5	546.4	442.6	480.5	392.8
127	535.8	565.5	522.8	556.8	553.5	537.5	428.9	515.0	540.4	436.3	492.6	401.7
128	536.3	574.8	527.1	564.2	552.1	544.9	405.0	522.7	547.8	444.2	482.8	395.3
129	533.4	572.6	524.0	561.9	549.2	541.7	421.4	517.9	544.7	441.4	488.6	398.3
130	519.2	553.3	511.8	545.0	542.1	532.4	421.5	509.8	537.8	419.2	483.9	383.0
131	546.6	577.3	530.2	573.9	549.3	544.8	383.0	521.3	552.4	450.7	476.6	390.0
132	448.3	466.0	440.2	465.2	465.8	460.2	322.3	436.5	459.5	355.6	411.9	315.1
133	432.8	448.9	432.1	451.4	453.9	448.6	374.9	427.6	445.2	327.2	417.9	305.6
134	431.6	445.6	431.5	448.6	452.6	447.7	391.7	426.4	442.9	323.9	423.3	310.1
135	378.6	373.0	373.7	379.6	374.3	376.4	444.0	359.4	374.6	276.7	403.3	304.8
139	350.3	371.7	346.8	361.2	375.9	367.5	325.7	352.0	362.4	272.1	345.7	257.5
140	361.8	380.7	357.1	369.5	384.7	375.1	334.1	357.5	369.6	281.2	356.1	270.5
141	364.5	387.0	361.3	373.8	393.7	383.0	352.9	366.5	376.2	284.6	367.0	278.9
144	354.2	373.9	346.7	360.6	381.5	370.5	324.0	354.3	364.6	273.3	348.3	259.7
145	351.5	372.4	345.7	360.7	380.0	369.1	340.9	352.9	363.7	271.9	353.1	263.6
146	349.7	369.9	347.4	354.1	380.8	366.5	413.9	353.8	361.0	267.5	375.9	279.7
147	381.6	399.9	378.3	395.5	407.8	399.2	469.8	378.8	393.0	284.0	415.6	302.8
149	639.4	663.8	602.8	642.5	648.4	635.3	463.6	601.2	630.7	481.8	566.2	431.5
150	618.9	647.2	588.1	628.4	620.9	612.5	444.6	587.6	617.5	467.9	545.3	410.2
151	627.5	646.4	589.1	624.0	621.7	617.0	453.0	590.8	618.1	471.5	553.2	419.2
152	633.5	654.0	595.0	628.8	627.8	624.0	457.4	594.9	624.2	476.5	558.8	423.8
153	607.4	636.4	578.8	619.9	613.0	602.4	453.9	573.1	599.3	450.0	532.8	395.6
154	626.9	652.3	589.7	626.8	626.4	617.6	457.7	587.7	616.4	469.1	551.9	416.4
155	629.0	653.9	594.7	628.4	628.0	622.0	477.7	590.6	619.9	473.3	563.0	426.5
156	629.0	647.9	594.1	627.6	625.4	619.6	470.0	589.0	618.0	471.2	560.0	425.0
157	624.9	648.2	591.8	626.5	623.6	617.3	479.5	587.4	616.8	469.7	562.7	426.8
158	621.2	645.9	588.9	620.5	620.9	613.7	484.5	584.6	613.7	466.9	562.1	425.4
159	626.3	650.3	592.3	626.4	623.8	618.0	479.9	589.9	618.8	470.9	563.8	428.2
160	389.9	405.0	367.8	350.5	403.7	400.7	195.6	384.9	379.7	290.8	321.9	243.3
161	370.6	383.3	366.7	351.6	392.8	380.9	401.1	367.3	369.0	274.9	382.0	284.9
162	371.1	381.3	368.2	350.3	393.3	380.8	420.0	367.1	368.3	273.9	388.6	291.4
163	370.6	380.6	367.3	342.9	392.1	378.8	423.4	365.8	364.6	271.2	389.6	292.4

ENGINE EXHAUST TEMPERATURES (DEG. C)

RUN #	CYL. #1L	CYL. #1R	CYL. #2L	CYL. #2R	CYL. #3L	CYL. #3R	CYL. #4L (TEST-CYL.)	CYL. #4R	RB-TUR IN TEMP.	RB-TUR OUT TEMP.	LB-TUR IN TEMP.	LB-TUR OUT TEMP.
164	370.0	381.4	367.5	349.1	392.6	379.4	427.3	365.5	366.6	271.7	391.1	294.1
165	367.5	381.3	365.7	368.1	393.9	378.9	345.2	368.2	372.4	282.2	363.7	274.5
166	368.6	383.3	366.7	368.9	395.9	380.2	347.1	369.2	373.8	283.3	366.6	278.2
167	427.9	445.1	417.4	442.6	446.2	436.0	335.6	419.7	435.8	325.6	399.3	296.9
168	429.3	445.5	417.3	443.2	447.9	439.1	326.0	421.3	437.6	327.8	396.9	295.6
169	431.1	449.2	418.3	444.1	448.8	440.2	325.4	419.8	438.6	329.0	397.3	296.0
170	489.3	518.3	472.8	499.4	513.4	499.4	326.3	476.8	497.9	366.8	436.9	316.6
171	489.4	515.4	473.9	497.2	512.5	497.1	331.7	476.3	496.9	365.9	439.9	319.6
172	599.3	635.2	571.6	605.9	599.4	592.0	389.8	566.0	591.1	472.4	512.2	402.5
173	600.2	632.6	572.6	601.2	598.2	587.6	389.9	563.4	590.2	472.1	515.9	407.9
174	380.4	396.8	379.9	335.0	403.6	390.3	357.5	377.8	372.0	280.2	366.2	283.0
175	434.5	436.7	422.2	432.5	452.5	431.7	406.1	412.8	426.8	311.5	414.0	315.1
176	432.2	436.4	421.2	432.2	452.1	432.6	416.6	414.5	427.4	312.2	418.5	316.6
177	436.4	438.7	423.1	434.6	453.6	433.9	409.3	414.6	429.5	314.2	419.0	317.9
178	429.0	454.5	417.8	443.3	445.6	441.5	303.3	422.9	438.7	326.7	370.1	284.0
179	427.3	451.6	417.6	442.8	445.8	439.7	334.4	420.9	438.1	326.4	379.6	292.3
180	427.7	451.2	418.7	442.0	447.5	439.7	338.9	419.9	437.6	325.9	381.0	295.1
181	424.5	447.9	418.6	438.9	443.7	437.4	364.9	415.8	434.9	323.0	391.8	299.6
182	424.7	446.7	419.6	437.2	443.6	436.7	383.1	414.7	433.5	321.1	390.7	304.4
183	423.8	445.1	418.0	435.5	442.3	433.1	401.1	412.8	431.2	318.7	367.4	308.8
184	424.6	441.3	418.5	434.3	444.9	432.5	408.7	412.1	430.2	316.9	383.7	312.4
185	433.9	440.7	419.4	434.4	454.6	432.7	407.6	412.2	429.7	315.9	423.2	316.0
186	437.1	439.4	418.7	434.7	456.2	432.9	398.9	413.6	430.0	315.9	404.6	316.0
187	437.3	438.8	420.7	433.9	455.5	432.0	410.3	412.9	429.8	315.8	409.6	318.6
188	436.0	438.2	419.2	432.5	453.6	430.7	407.1	411.9	427.9	314.2	392.4	317.6
189	434.7	457.1	420.0	447.5	449.9	445.3	304.7	425.8	442.3	331.0	373.8	292.2
190	426.3	452.1	417.1	443.4	445.2	442.1	307.6	422.3	434.5	321.0	387.9	275.5
191	425.9	447.7	421.4	443.2	445.6	441.1	348.2	422.1	436.8	323.3	418.1	293.0
192	426.8	448.0	421.8	442.0	443.7	440.7	355.4	421.2	437.0	322.8	338.5	296.6
193	425.9	443.6	423.2	439.8	444.3	438.8	380.6	421.5	435.8	321.7	401.1	303.3
194	428.4	443.3	424.0	439.7	445.3	438.4	393.7	421.6	436.1	321.5	333.0	308.1
195	429.7	440.0	424.2	437.6	446.1	436.3	424.5	417.6	432.7	318.2	437.7	315.7
196	438.4	440.4	424.4	438.2	453.8	435.8	408.4	417.2	433.3	317.9	384.5	318.2
197	427.2	445.3	422.3	442.1	445.0	439.9	364.9	420.4	437.3	322.4	384.1	302.4
198	195.7	202.6	202.0	214.9	194.0	183.4	112.3	196.6	216.9	224.2	-137.8	186.2
199	418.5	442.5	395.1	433.0	435.6	435.0	203.5	417.9	425.6	315.6	224.5	247.5
200	415.8	440.8	404.3	434.7	435.4	434.4	309.4	415.5	430.4	320.4	214.0	274.8
201	417.1	434.4	405.6	431.6	435.6	432.3	312.2	415.1	429.3	317.0	107.0	280.4
202	413.1	432.6	405.3	431.0	435.0	430.6	333.3	413.5	427.8	314.9	-47895.0	284.7
203	410.8	427.7	405.5	428.3	434.8	428.7	370.1	412.5	425.8	312.5	713.3	292.8
204	409.5	428.3	405.1	426.7	434.1	427.9	373.3	410.4	424.4	310.8	-12.4	293.9
205	410.0	428.8	406.8	426.2	434.7	427.3	398.0	410.3	423.9	309.9	-26898.0	299.9
206	406.6	423.4	405.4	421.9	432.7	423.8	409.9	408.5	420.6	306.6	812.6	301.9
207	410.5	424.1	406.9	420.7	434.4	424.5	444.0	406.8	420.2	305.7	45.4	311.2
208	424.1	422.0	408.1	420.4	441.1	422.4	434.8	404.5	418.3	303.4	424.0	314.0

ENGINE EXHAUST TEMPERATURES (DEG. C)

RUN #	CYL. #1L	CYL. #1R	CYL. #2L	CYL. #2R	CYL. #3L	CYL. #3R	CYL. #4L (TEST- CYL.)	CYL. #4R	RB-TUR IN TEMP.	RB-TUR OUT TEMP.	LB-TUR IN TEMP.	LB-TUR OUT TEMP.
209	418.7	438.0	409.9	432.0	437.5	434.8	322.3	418.2	430.8	317.0	557.6	290.2
210	420.9	446.8	412.4	440.0	442.4	440.9	296.6	418.7	434.7	320.7	198.0	275.8
211	421.8	442.1	411.4	440.5	442.6	438.0	294.9	418.9	434.2	320.9	239.1	277.6
212	421.4	442.0	411.1	439.9	441.3	439.7	296.4	418.8	435.2	321.6	193.9	279.2
213	423.9	442.0	412.3	441.0	442.2	440.6	295.1	420.3	436.5	323.1	437.7	279.9
214	421.4	442.8	413.4	440.3	441.8	439.1	321.1	418.9	435.7	322.5	340.8	285.4
215	420.9	442.1	413.1	439.6	441.0	438.5	327.5	418.9	435.4	321.5	302.8	287.6
216	418.5	438.0	411.7	435.8	438.3	435.4	341.2	416.8	432.4	318.6	90.5	289.5
217	419.5	439.0	412.9	437.4	439.4	435.6	346.0	417.7	433.7	319.0	-0.7	292.1
218	423.6	440.5	406.3	440.8	441.2	439.4	272.6	421.0	438.2	327.7	376.8	275.6
219	423.2	439.1	405.9	438.7	440.6	439.1	273.3	420.1	437.2	326.4	377.1	276.0
221	431.9	448.6	412.9	446.6	446.7	444.7	272.9	426.7	443.1	332.1	381.4	278.9
222	432.2	448.2	413.6	448.2	449.4	445.0	274.8	428.1	444.0	332.9	382.9	281.2
223	430.2	452.5	397.1	443.6	447.7	445.9	211.5	426.0	443.8	347.2	353.2	270.4
224	422.7	440.0	396.7	431.8	438.8	441.2	205.0	420.6	427.2	315.4	343.0	249.0
225	426.3	443.0	400.8	435.7	439.5	442.8	210.0	423.3	433.1	322.3	348.4	254.8
226	424.7	436.6	404.9	433.7	437.0	438.1	260.5	417.6	432.7	320.0	370.5	266.4
227	424.7	434.7	403.4	432.1	437.3	437.3	258.9	416.9	431.8	318.5	370.7	268.0
228	424.1	439.3	404.7	434.0	439.3	438.1	255.9	417.8	433.4	319.9	369.2	268.2
229	420.4	438.0	404.9	433.8	438.3	437.1	280.2	418.1	432.8	318.8	378.1	274.2
230	413.1	431.1	403.6	426.9	433.6	431.0	331.4	414.0	427.3	313.3	392.6	283.1
231	414.3	432.1	405.2	427.8	412.2	432.3	318.4	415.4	428.1	314.0	389.2	282.4
232	410.1	428.4	401.8	423.7	417.1	428.0	354.9	410.6	423.7	309.0	398.3	288.0
233	410.4	428.5	403.3	423.5	431.8	428.7	358.8	411.7	424.1	309.1	400.7	290.6
234	410.1	427.8	402.9	420.8	590.5	427.7	364.1	410.3	422.8	307.5	401.9	291.0
235	408.5	428.5	402.9	422.9	406.6	429.5	366.9	410.5	423.7	308.0	403.3	292.3
236	411.3	432.5	400.6	424.7	431.5	432.3	290.4	413.7	422.2	309.2	373.8	267.7
237	411.6	434.5	401.3	425.9	434.5	432.4	290.9	413.9	424.4	311.7	375.8	270.8
238	418.5	440.3	402.2	432.7	440.9	438.6	270.3	419.0	433.1	320.2	372.7	273.2
239	416.0	437.2	403.7	430.5	436.0	435.3	299.8	416.5	430.1	317.9	382.6	279.1
240	412.5	430.4	401.4	427.1	435.1	431.8	325.2	414.8	427.4	315.2	390.0	283.6
241	412.1	430.3	401.9	425.8	412.0	432.1	326.5	414.2	426.8	314.2	390.4	284.6
242	409.7	426.8	400.2	423.7	481.2	429.6	355.0	413.2	424.0	311.6	399.0	289.6
243	409.2	426.2	401.7	422.1	518.5	428.6	372.7	411.9	423.5	310.2	404.8	294.7
244	417.4	434.0	403.0	427.1	438.2	433.7	309.0	416.3	428.7	315.2	387.0	284.7
245	416.4	433.2	401.1	427.6	476.5	434.3	304.6	416.0	428.7	315.9	384.8	281.8
246	701.4	697.4	594.4	676.4	682.9	667.3	229.3	633.6	654.7	503.7	504.8	377.8
247	691.3	694.5	608.7	672.2	672.2	668.1	272.4	635.5	663.7	518.7	528.4	397.7
248	677.6	689.6	614.1	663.3	662.5	658.3	319.3	630.2	662.8	519.0	542.6	411.9
249	672.1	692.8	617.3	660.1	662.0	659.5	332.0	628.3	661.9	517.8	546.6	414.8
250	661.9	684.0	614.6	653.5	660.9	654.2	352.2	624.5	655.4	510.7	549.7	417.9
251	663.6	679.7	615.8	654.5	659.7	653.6	346.6	623.4	654.3	509.7	549.9	417.8
252	660.1	683.7	618.1	653.4	661.9	653.2	378.1	623.5	654.0	508.9	559.0	424.7
253	657.3	680.4	616.2	652.9	660.3	649.8	375.3	622.7	652.6	507.0	557.6	424.5
254	720.0	716.8	610.2	692.3	694.5	670.8	230.4	643.0	664.4	513.0	512.8	385.9
255	685.1	690.5	616.2	670.2	661.3	658.7	316.3	631.4	659.2	514.2	537.1	403.6
256	685.2	687.6	619.3	666.0	663.5	659.3	320.6	631.0	659.4	514.4	541.5	408.2
257	679.1	688.2	616.0	666.4	664.5	659.3	335.9	628.8	660.7	516.1	546.4	413.9
258	674.0	688.1	616.9	661.5	665.7	655.2	349.1	629.3	659.5	514.4	549.9	417.2
259	669.8	690.7	621.3	665.2	669.9	656.8	375.8	629.7	661.5	516.2	561.0	427.2
260	667.2	683.2	617.6	658.6	664.5	653.6	366.3	626.8	657.5	511.7	555.7	423.1
261	670.9	691.7	621.8	663.1	670.2	657.1	367.1	630.8	661.9	515.6	559.8	426.8

ENGINE EXHAUST TEMPERATURES (DEG. C)

RUN #	CYL. #1L	CYL. #1R	CYL. #2L	CYL. #2R	CYL. #3L	CYL. #3R	CYL.-#4L (TEST- CYL.)	CYL. #4R	RB-TUR IN TEMP.	RB-TUR OUT TEMP.	LB-TUR IN TEMP.	LB-TUR OUT TEMP.
262	666.4	680.9	618.0	656.9	663.9	651.4	376.6	624.9	655.3	509.9	558.4	425.3
263	669.3	686.7	624.7	663.7	671.2	656.8	383.4	630.7	660.4	514.7	564.1	430.6
264	705.5	712.6	601.8	685.7	684.9	668.6	232.8	635.2	662.2	513.7	509.6	385.1
265	666.5	674.6	608.5	657.4	650.4	650.7	334.9	620.8	649.8	506.3	535.8	402.4
266	721.1	726.3	616.0	699.9	701.4	682.1	236.1	651.4	684.5	536.8	525.3	402.4
267	721.5	723.2	616.3	690.8	701.5	679.5	231.3	648.1	671.1	519.6	517.7	393.1
268	678.1	697.7	622.8	670.6	668.2	667.8	341.1	633.8	667.8	525.3	549.3	415.3
269	436.0	455.2	410.7	446.8	457.9	451.7	190.8	432.7	434.9	320.6	349.3	251.0
270	424.0	447.1	420.4	440.5	454.7	446.1	312.4	426.2	436.4	325.6	391.8	285.0
271	427.7	446.7	419.6	442.8	455.2	446.5	314.8	427.5	440.1	329.7	396.9	292.8
272	427.9	447.9	420.5	442.4	456.1	447.7	325.4	428.5	440.8	330.8	401.1	296.4
273	424.0	445.4	421.3	439.3	455.6	444.1	362.3	425.6	438.1	328.0	411.8	303.3
274	725.0	725.0	619.9	699.2	707.2	684.2	228.0	652.9	669.5	509.4	517.1	385.1
275	677.9	700.4	628.7	675.9	673.8	671.2	364.4	641.4	669.4	524.4	559.9	423.6
276	434.8	465.6	433.7	457.9	467.8	457.0	345.6	435.0	457.7	346.6	415.5	306.0
277	715.7	723.3	610.9	691.6	692.9	678.2	230.0	644.9	666.2	514.9	512.5	384.0
278	686.0	703.0	627.1	679.8	667.9	671.9	324.3	642.7	673.5	530.7	546.3	411.9
279	428.8	456.6	407.1	444.4	453.7	449.9	195.5	426.9	446.5	342.2	358.6	269.3
280	426.3	454.6	421.9	443.9	459.9	448.0	329.0	429.2	444.8	336.9	401.1	293.0
281	430.3	457.7	422.5	446.1	461.2	452.1	306.6	432.5	447.1	338.2	396.6	294.3
282	429.3	456.3	422.5	445.2	459.2	448.7	314.6	431.7	445.5	337.5	397.3	295.0
283	424.6	450.3	424.6	441.3	459.4	447.4	351.8	428.7	442.4	332.8	411.0	304.2
284	434.7	460.1	427.1	449.3	464.2	452.9	304.2	435.2	449.9	341.8	398.0	297.6
285	437.6	466.7	416.6	452.9	463.5	459.2	198.9	438.2	449.8	340.9	362.0	266.9
286	424.9	454.4	422.5	444.1	458.9	448.4	328.5	430.2	443.0	334.7	399.4	290.7
287	433.7	462.7	424.6	450.3	463.0	452.4	290.7	435.5	450.2	341.7	394.2	294.1
288	432.0	460.9	425.5	448.9	463.0	452.7	310.1	434.6	449.0	341.2	399.3	296.6
289	424.0	453.4	424.3	443.8	459.0	448.0	365.5	430.0	444.0	335.7	413.2	304.6
290	424.6	450.3	422.9	441.2	457.6	446.4	372.1	428.2	442.1	332.9	414.5	306.1
291	428.4	455.0	425.4	446.7	460.2	448.0	361.3	430.3	445.8	336.5	412.7	308.4
292	430.1	456.5	424.2	448.7	461.1	451.3	336.2	434.0	447.8	338.8	405.4	303.1
293	425.0	455.7	426.8	446.9	459.5	448.6	379.6	429.5	445.4	335.5	420.1	311.0
294	424.9	454.8	426.0	446.1	460.3	447.9	377.6	429.9	445.5	335.0	420.0	311.1
295	427.4	458.5	426.7	449.2	461.5	449.2	351.9	431.2	447.5	337.3	413.5	308.0
296	427.0	457.9	425.4	449.5	461.7	449.6	350.3	431.1	447.4	337.9	412.4	306.4
297	433.8	464.8	412.5	454.7	458.3	455.8	196.5	437.4	448.6	339.0	356.6	260.7
298	425.3	457.5	419.4	448.7	455.0	447.2	301.4	427.4	444.9	336.0	389.8	283.3
299	430.5	461.3	422.5	453.1	459.2	451.0	317.1	430.9	449.6	340.6	399.1	295.9
300	432.3	460.4	422.2	453.0	459.4	452.0	318.9	431.6	450.1	341.1	399.3	295.9
301	431.4	460.2	423.7	452.1	458.5	451.0	332.0	430.3	449.2	340.0	404.1	299.0
302	431.8	462.0	423.2	454.1	459.8	453.0	313.6	432.9	450.6	341.3	399.6	295.7
303	431.6	460.4	422.0	452.1	458.2	452.2	313.6	430.9	449.6	339.5	398.4	294.5
304	434.1	463.9	422.5	455.4	461.0	455.0	296.6	433.1	452.4	341.9	394.8	293.4
305	430.7	461.6	421.4	453.3	459.2	453.6	314.2	433.4	450.8	341.2	399.4	294.9
306	433.0	463.5	421.2	454.5	460.2	453.7	303.8	433.3	451.2	342.0	397.1	294.0
307	431.7	462.5	420.5	452.0	457.9	451.4	307.0	431.6	449.5	340.2	397.1	293.5
308	427.6	458.6	421.6	448.5	456.7	449.2	358.5	430.6	446.2	338.3	410.3	299.8
309	423.3	451.9	422.3	443.5	452.9	445.1	388.0	426.7	442.6	332.6	418.3	306.6
310	428.2	454.9	423.0	447.4	454.9	446.7	368.2	427.7	444.9	335.2	413.0	305.4
311	428.5	454.2	423.4	445.3	456.1	447.1	379.5	427.9	444.4	334.1	417.1	308.1
312	430.7	457.7	423.1	447.8	457.2	448.8	340.5	429.5	446.8	336.7	407.0	300.3
313	435.4	462.5	425.2	450.6	458.8	452.7	318.8	433.3	449.7	340.2	400.9	297.3

ENGINE EXHAUST TEMPERATURES (DEG. C)

RUN #	CYL. #1L	CYL. #1R	CYL. #2L	CYL. #2R	CYL. #3L	CYL. #3R	CYL.-#4L (TEST- CYL.)	CYL. #4R	RB-TUR IN TEMP.	RB-TUR OUT TEMP.	LB-TUR IN TEMP.	LB-TUR OUT TEMP.
314	434.8	461.1	424.4	452.3	458.3	452.4	334.8	432.7	449.7	340.6	404.9	299.9
315	425.3	453.4	422.3	444.8	454.5	447.0	392.9	427.1	443.5	334.3	419.0	308.5
316	432.0	462.1	412.5	447.4	454.5	454.6	193.2	432.8	438.6	327.8	350.7	252.3
317	422.5	453.8	421.7	441.9	451.5	446.8	320.0	427.8	438.2	330.6	391.8	281.3
318	424.0	453.6	422.2	442.8	455.4	448.6	327.1	428.1	442.7	334.4	399.7	293.1
319	422.9	454.2	422.0	443.4	454.8	449.1	325.7	429.1	443.8	335.1	399.5	293.5
320	422.7	453.2	422.2	442.5	454.7	449.0	351.1	429.1	443.6	335.2	406.6	298.7
321	422.4	453.4	422.5	442.8	455.4	448.9	352.5	429.7	443.6	335.6	409.3	301.1
322	423.6	453.1	420.3	443.2	453.6	446.8	365.4	428.2	442.7	336.4	409.6	299.9
323	420.6	449.7	421.3	440.6	452.5	444.9	384.7	425.5	440.7	333.1	415.8	305.5
324	424.4	454.7	418.0	444.5	453.1	447.6	356.8	428.8	443.9	337.2	406.6	300.3
325	418.9	449.2	415.8	439.7	449.6	443.9	395.0	426.4	440.3	333.1	415.2	305.4
326	417.9	443.6	418.8	436.9	449.9	440.1	442.6	421.9	436.5	327.9	430.7	316.1
327	420.1	441.8	419.6	437.1	452.5	439.1	451.8	421.6	435.5	327.0	437.3	321.2
328	419.0	443.8	419.9	438.5	451.1	441.7	446.3	422.4	437.5	328.5	434.3	319.2
329	421.1	441.9	421.0	437.2	453.5	440.4	444.3	420.0	436.2	326.7	438.5	322.1
330	432.6	455.8	425.4	448.6	460.2	448.6	332.0	428.0	444.0	338.8	403.2	298.9
331	433.1	455.5	425.9	449.0	460.3	449.4	330.2	427.9	444.3	339.5	404.2	300.4
332	456.7	450.0	454.0	455.7	470.0	439.3	311.4	437.8	457.8	388.2	412.0	343.5
333	473.6	456.6	463.1	464.0	471.7	444.5	271.7	444.6	464.1	395.0	402.8	340.3
334	307.7	299.7	310.2	306.9	318.4	290.5	308.2	294.0	317.2	303.9	321.2	298.2
335	300.9	288.7	310.3	300.1	309.0	280.2	315.4	286.8	309.9	295.0	319.4	297.5
336	291.0	278.1	293.1	289.4	301.2	269.4	335.2	275.6	289.7	267.9	312.3	287.1
337	295.2	277.7	299.7	288.4	300.2	269.0	313.3	276.1	288.4	266.2	306.7	283.0
338	318.9	309.8	323.1	314.2	333.5	289.6	312.9	297.4	308.3	285.4	324.3	302.3
339	321.0	311.0	324.8	314.8	334.8	289.9	310.0	298.0	308.2	286.6	324.5	303.9
340	322.4	309.8	325.1	315.7	332.1	290.6	302.0	298.6	308.7	287.8	321.9	302.4

ENGINE CONFIGURATION AND AMBIENT CONDITIONS

RUN #	BORE (m)	STROKE (m)	# CYL.	COMP. RATIO	LHV DF2 (kJ/kg)	LHV TES FUEL (kJ/kg)	ENG. DISP. (m3)	CHARGE EFFIC.	RH (%)	AMBIENT TEMP. (DEG. C)	BARO. PRESS. (kPa)
1	0.1461	0.1461	8	15	42800	42800	0.0196	0.799	18	33.9	98.8
2	0.1461	0.1461	8	15	42800	42800	0.0196	0.801	16	33.9	98.7
3	0.1461	0.1461	8	15	42800	42800	0.0196	0.796	20	33.3	98.7
4	0.1461	0.1461	8	15	42800	42800	0.0196	0.879	17	33.9	98.7
5	0.1461	0.1461	8	15	42800	42800	0.0196	0.875	15	33.9	98.7
6	0.1461	0.1461	8	15	42800	42800	0.0196	0.860	13	35.0	98.6
7	0.1461	0.1461	8	15	42800	42800	0.0196	0.819	12	36.1	98.6
8	0.1461	0.1461	8	15	42800	42800	0.0196	0.802	10	35.0	98.6
9	0.1461	0.1461	8	15	42800	42800	0.0196	0.792	8	37.8	98.6
10	0.1461	0.1461	8	15	42800	42800	0.0196	0.790	8	38.3	98.6
11	0.1461	0.1461	8	15	42800	42800	0.0196	0.853	34	30.6	98.9
12	0.1461	0.1461	8	15	42800	42800	0.0196	0.809	31	31.7	98.9
13	0.1461	0.1461	8	15	42800	42800	0.0196	0.890	27	32.2	98.9
14	0.1461	0.1461	8	15	42800	42800	0.0196	0.874	28	31.7	98.9
15	0.1461	0.1461	8	15	42800	42800	0.0196	0.861	18	32.2	98.8
16	0.1461	0.1461	8	15	42800	42800	0.0196	0.847	14	35.6	98.7
17	0.1461	0.1461	8	15	42800	42800	0.0196	0.820	13	36.1	98.7
18	0.1461	0.1461	8	15	42800	42800	0.0196	0.798	13	36.1	98.7
19	0.1461	0.1461	8	15	42800	42800	0.0196	0.900	13	35.0	98.7
20	0.1461	0.1461	8	19	42800	42800	0.0196	0.901	23	33.9	98.5
21	0.1461	0.1461	8	19	42800	42800	0.0196	0.900	21	33.9	98.5
22	0.1461	0.1461	8	19	42800	42800	0.0196	0.900	20	32.8	98.5
23	0.1461	0.1461	8	19	42800	42800	0.0196	0.900	17	33.9	98.4
24	0.1461	0.1461	8	19	42800	42800	0.0196	0.900	17	35.0	98.4
25	0.1461	0.1461	8	19	42800	42800	0.0196	0.903	15	36.1	98.4
26	0.1461	0.1461	8	19	42800	42800	0.0196	0.846	14	35.0	98.4
27	0.1461	0.1461	8	19	42800	42800	0.0196	0.900	20	30.0	98.3
28	0.1461	0.1461	8	19	42800	42800	0.0196	0.900	16	31.7	98.3
29	0.1461	0.1461	8	19	42800	42800	0.0196	0.900	15	32.2	98.2
30	0.1461	0.1461	8	19	42800	42800	0.0196	0.903	15	31.1	98.2
31	0.1461	0.1461	8	19	42800	42800	0.0196	0.904	13	32.2	98.2
32	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	9	28.9	98.8
33	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	9	28.9	98.8
34	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	9	26.1	98.8
35	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	9	27.8	98.8
36	0.1461	0.1461	8	19	42800	20000	0.0196	0.845	9	27.8	98.8
37	0.1461	0.1461	8	19	42800	20000	0.0196	0.846	9	28.3	98.8
38	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	42	23.3	98.8
39	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	42	22.8	98.8
40	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	41	24.5	98.8
41	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	41	23.9	98.8
42	0.1461	0.1461	8	19	42800	20000	0.0196	0.846	41	23.3	98.8
43	0.1461	0.1461	8	19	42800	20000	0.0196	0.847	41	23.3	98.8
44	0.1461	0.1461	8	19	42800	20000	0.0196	0.847	40	23.9	98.8
45	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	41	23.9	98.8
46	0.1461	0.1461	8	19	42800	20000	0.0196	0.903	49	24.5	98.7
47	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	44	26.1	98.7
48	0.1461	0.1461	8	19	42800	20000	0.0196	0.902	44	25.6	98.7
49	0.1461	0.1461	8	19	42800	20000	0.0196	0.845	42	26.7	98.7
50	0.1461	0.1461	8	19	42800	0	0.0196	0.851	31	30.0	98.5
51	0.1461	0.1461	8	19	42800	20000	0.0196	0.849	29	30.0	98.5
52	0.1461	0.1461	8	19	42800	14500	0.0196	0.848	30	30.6	98.5

ENGINE CONFIGURATION AND AMBIENT CONDITIONS

RUN #	BORE (m)	STROKE (m)	# CYL.	COMP. RATIO	LHV DF2 (kJ/kg)	LHV TES FUEL (kJ/kg)	ENG. DISP. (m3)	CHARGE EFFIC.	RH (%)	AMBIENT TEMP. (DEG. C)	BARO. PRESS. (kPa)
53	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	27	31.7	98.5
54	0.1461	0.1461	8	19	42800	14500	0.0196	0.848	27	29.5	98.5
55	0.1461	0.1461	8	19	42800	0	0.0196	0.853	17	33.3	98.4
56	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	17	32.8	98.4
57	0.1461	0.1461	8	19	42800	14500	0.0196	0.847	18	32.2	98.4
58	0.1461	0.1461	8	19	42800	20000	0.0196	0.847	16	35.0	98.4
59	0.1461	0.1461	8	19	42800	14500	0.0196	0.848	17	33.9	98.3
60	0.1461	0.1461	8	19	42800	14500	0.0196	0.847	16	34.5	98.4
61	0.1461	0.1461	8	19	42800	20000	0.0196	0.850	19	32.8	98.4
62	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	19	32.2	98.4
63	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	19	31.7	98.4
64	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	19	31.7	98.4
65	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	19	32.2	98.4
66	0.1461	0.1461	8	19	42800	20000	0.0196	0.849	20	31.7	98.4
67	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	20	32.2	98.4
68	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	20	32.2	98.4
69	0.1461	0.1461	8	19	42800	0	0.0196	0.900	44	28.3	98.6
70	0.1461	0.1461	8	19	42800	0	0.0196	0.852	56	26.7	98.8
71	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	56	26.7	98.8
72	0.1461	0.1461	8	19	42800	14500	0.0196	0.848	52	27.2	98.8
73	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	54	26.7	98.7
74	0.1461	0.1461	8	19	42800	14500	0.0196	0.848	51	28.3	98.7
75	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	50	28.3	98.7
76	0.1461	0.1461	8	19	42800	20000	0.0196	0.847	53	27.2	98.7
77	0.1461	0.1461	8	19	42800	14500	0.0196	0.848	53	27.2	98.7
78	0.1461	0.1461	8	19	42800	14500	0.0196	0.848	53	27.2	98.7
79	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	57	26.7	99.2
80	0.1461	0.1461	8	19	42800	14500	0.0196	0.847	57	26.7	98.8
81	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	57	26.7	98.8
82	0.1461	0.1461	8	19	42800	20000	0.0196	0.842	56	26.7	98.8
83	0.1461	0.1461	8	19	42800	0	0.0196	0.900	23	28.3	98.8
84	0.1461	0.1461	8	19	42800	0	0.0196	0.900	25	28.3	98.8
85	0.1461	0.1461	8	19	42800	0	0.0196	0.900	24	28.9	98.8
86	0.1461	0.1461	8	19	42800	0	0.0196	0.853	17	31.1	99.3
87	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	18	31.7	99.3
88	0.1461	0.1461	8	19	42800	14500	0.0196	0.847	16	30.6	99.3
89	0.1461	0.1461	8	19	42800	20000	0.0196	0.849	17	30.6	99.3
90	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	16	30.6	99.3
91	0.1461	0.1461	8	19	42800	14500	0.0196	0.845	16	29.5	99.2
92	0.1461	0.1461	8	19	42800	20000	0.0196	0.847	16	30.6	99.2
93	0.1461	0.1461	8	19	42800	20000	0.0196	0.847	16	31.1	99.2
94	0.1461	0.1461	8	19	42800	14500	0.0196	0.846	15	31.1	99.2
95	0.1461	0.1461	8	19	42800	14500	0.0196	0.844	15	31.7	99.2
96	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	15	30.6	99.2
97	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	26	31.1	99.5
98	0.1461	0.1461	8	19	42800	20000	0.0196	0.846	20	31.1	99.5
99	0.1461	0.1461	8	19	42800	14500	0.0196	0.846	20	31.7	99.4
100	0.1461	0.1461	8	19	42800	14500	0.0196	0.845	21	32.2	99.4
101	0.1461	0.1461	8	19	42800	20000	0.0196	0.848	9	28.3	97.9
102	0.1461	0.1461	8	19	42800	14500	0.0196	0.847	9	28.9	97.9
103	0.1461	0.1461	8	19	42800	20000	0.0196	0.836	9	28.3	97.9
104	0.1461	0.1461	8	19	42800	0	0.0196	0.845	36	8.9	99.4

ENGINE CONFIGURATION AND AMBIENT CONDITIONS

RUN #	BORE (m)	STROKE (m)	# CYL.	COMP. RATIO	LHV DF2 (kJ/kg)	LHV TEST FUEL (kJ/kg)	ENG. DISP. (m3)	CHARGE EFFIC.	RH (%)	AMB. TEM (DEG. C)	BARO (kPa)
105	0.1461	0.1461	8	19	42800	20000	0.0196	0.843	35	8.9	99.3
106	0.1461	0.1461	8	19	42800	20000	0.0196	0.843	34	10.6	99.3
107	0.1461	0.1461	8	19	42800	20000	0.0196	0.844	20	13.9	99.1
108	0.1461	0.1461	8	19	42800	0	0.0196	0.846	15	13.9	99.1
109	0.1461	0.1461	8	19	42800	20000	0.0196	0.773	18	22.2	80.1
110	0.1461	0.1461	8	19	42800	0	0.0196	0.900	17	23.9	80.1
111	0.1461	0.1461	8	19	42800	20000	0.0196	0.773	21	21.7	80.1
112	0.1461	0.1461	8	19	42800	20000	0.0196	0.776	20	21.1	80.1
113	0.1461	0.1461	8	19	42800	0	0.0196	0.781	20	21.1	80.1
114	0.1461	0.1461	8	19	42800	20000	0.0196	0.819	32	20.6	97.5
115	0.1461	0.1461	8	19	42800	20000	0.0196	0.807	32	20.0	97.5
116	0.1461	0.1461	8	19	42800	20000	0.0196	0.825	12	23.9	99.0
117	0.1461	0.1461	8	19	42800	20000	0.0196	0.827	12	23.3	99.0
118	0.1461	0.1461	8	19	42800	20000	0.0196	0.857	42	17.2	98.8
120	0.1461	0.1461	8	19	42800	20000	0.0196	0.828	44	15.6	98.6
121	0.1461	0.1461	8	19	42800	14500	0.0196	0.826	44	15.6	98.6
122	0.1461	0.1461	8	19	42800	14500	0.0196	0.827	46	15.6	98.6
123	0.1461	0.1461	8	19	42800	20000	0.0196	0.829	45	16.1	98.6
124	0.1461	0.1461	8	19	42800	14500	0.0196	0.827	44	15.0	98.6
125	0.1461	0.1461	8	19	42800	20000	0.0196	0.826	43	16.7	98.6
126	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	43	16.1	98.6
127	0.1461	0.1461	8	19	42800	14500	0.0196	0.826	43	15.6	98.6
128	0.1461	0.1461	8	19	42800	20000	0.0196	0.830	42	16.1	98.6
129	0.1461	0.1461	8	19	42800	14500	0.0196	0.817	41	17.2	98.6
130	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	41	16.7	98.6
131	0.1461	0.1461	8	19	42800	20000	0.0196	0.830	13	19.5	99.2
132	0.1461	0.1461	8	19	42800	14500	0.0196	0.823	13	20.0	99.2
133	0.1461	0.1461	8	19	42800	14500	0.0196	0.826	12	22.2	99.2
134	0.1461	0.1461	8	19	42800	14500	0.0196	0.825	12	21.7	99.2
135	0.1461	0.1461	8	19	42800	14500	0.0196	0.837	12	20.6	99.2
139	0.1461	0.1461	8	19	42800	20000	0.0196	0.843	20	15.0	98.8
140	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	20	15.0	98.8
141	0.1461	0.1461	8	19	42800	14500	0.0196	0.849	-3	15.0	98.7
144	0.1461	0.1461	8	19	42800	20000	0.0196	0.845	28	15.6	98.5
145	0.1461	0.1461	8	19	42800	14500	0.0196	0.844	28	15.6	98.5
146	0.1461	0.1461	8	19	42800	14500	0.0196	0.841	29	15.6	98.5
147	0.1461	0.1461	8	19	42800	14500	0.0196	0.829	29	15.6	98.4
149	0.1461	0.1461	8	19	42800	20000	0.0196	0.796	18	31.7	98.2
150	0.1461	0.1461	8	19	42800	20000	0.0196	0.790	47	18.3	99.1
151	0.1461	0.1461	8	19	42800	14500	0.0196	0.792	46	18.9	99.1
152	0.1461	0.1461	8	19	42800	14500	0.0196	0.797	45	19.5	99.1
153	0.1461	0.1461	8	19	42800	20000	0.0196	0.790	46	18.9	99.1
154	0.1461	0.1461	8	19	42800	14500	0.0196	0.792	45	20.0	99.0
155	0.1461	0.1461	8	19	42800	14500	0.0196	0.788	44	20.0	99.0
156	0.1461	0.1461	8	19	42800	14500	0.0196	0.790	44	20.6	99.0
157	0.1461	0.1461	8	19	42800	14500	0.0196	0.791	44	20.0	99.0
158	0.1461	0.1461	8	19	42800	14500	0.0196	0.793	43	20.0	99.0
159	0.1461	0.1461	8	19	42800	14500	0.0196	0.793	43	20.6	99.0
160	0.1461	0.1461	8	19	42800	0	0.0196	0.847	31	22.8	98.7
161	0.1461	0.1461	8	19	42800	14500	0.0196	0.842	31	22.8	98.7
162	0.1461	0.1461	8	19	42800	14500	0.0196	0.841	31	22.8	98.7
163	0.1461	0.1461	8	19	42800	14500	0.0196	0.842	31	22.2	98.7

ENGINE CONFIGURATION AND AMBIENT CONDITIONS

RUN #	BORE (m)	STROKE (m)	# CYL.	COMP. RATIO	LHV DF2 (kJ/kg)	LHV TEST FUEL (kJ/kg)	ENG. DISP. (m3)	CHARGE EFFIC.	RH (%)	AMB. TEM (DEG. C)	BARO (kPa)
164	0.1461	0.1461	8	19	42800	14500	0.0196	0.840	31	22.2	98.7
165	0.1461	0.1461	8	19	42800	14500	0.0196	0.847	23	30.0	98.4
166	0.1461	0.1461	8	19	42800	14500	0.0196	0.848	23	29.5	98.4
167	0.1461	0.1461	8	19	42800	14500	0.0196	0.835	24	28.9	98.4
168	0.1461	0.1461	8	19	42800	14500	0.0196	0.837	24	30.6	98.3
169	0.1461	0.1461	8	19	42800	14500	0.0196	0.837	24	30.0	98.3
170	0.1461	0.1461	8	19	42800	14500	0.0196	0.825	22	29.5	98.3
171	0.1461	0.1461	8	19	42800	14500	0.0196	0.824	23	29.5	98.3
172	0.1461	0.1461	8	19	42800	20000	0.0196	0.822	23	31.1	98.3
173	0.1461	0.1461	8	19	42800	20000	0.0196	0.821	22	30.6	98.3
174	0.1461	0.1461	8	19	42800	20000	0.0196	0.845	26	30.0	97.7
175	0.1461	0.1461	8	19	42800	14500	0.0196	0.829	25	29.5	97.7
176	0.1461	0.1461	8	19	42800	14500	0.0196	0.828	26	29.5	97.7
177	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	26	29.5	97.7
178	0.1461	0.1461	8	19	42800	20000	0.0196	0.836	30	28.3	97.6
179	0.1461	0.1461	8	19	42800	14500	0.0196	0.834	30	28.9	97.6
180	0.1461	0.1461	8	19	42800	14500	0.0196	0.833	29	28.9	97.6
181	0.1461	0.1461	8	19	42800	14500	0.0196	0.833	28	29.5	97.6
182	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	28	30.0	97.6
183	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	27	29.5	97.6
184	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	27	30.0	97.6
185	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	27	29.5	97.6
186	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	27	29.5	97.6
187	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	27	30.0	97.6
188	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	27	30.6	97.6
189	0.1461	0.1461	8	19	42800	20000	0.0196	0.835	26	30.0	97.6
190	0.1461	0.1461	8	19	42800	20000	0.0196	0.834	25	30.0	97.6
191	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	26	30.6	97.6
192	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	27	30.6	97.6
193	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	26	30.0	97.6
194	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	26	30.0	97.6
195	0.1461	0.1461	8	19	42800	14500	0.0196	0.828	26	30.0	97.6
196	0.1461	0.1461	8	19	42800	14500	0.0196	0.826	26	29.5	97.6
197	0.1461	0.1461	8	19	42800	20000	0.0196	0.832	28	28.9	97.6
198	0.1461	0.1461	8	19	42800	20000	0.0196	0.900	13	24.5	98.7
199	0.1461	0.1461	8	19	42800	20000	0.0196	0.837	12	24.5	98.6
200	0.1461	0.1461	8	19	42800	20000	0.0196	0.834	12	25.0	98.7
201	0.1461	0.1461	8	19	42800	20000	0.0196	0.832	12	24.5	98.6
202	0.1461	0.1461	8	19	42800	20000	0.0196	0.833	12	25.0	98.6
203	0.1461	0.1461	8	19	42800	20000	0.0196	0.831	12	24.5	98.6
204	0.1461	0.1461	8	19	42800	20000	0.0196	0.821	12	25.0	94.7
205	0.1461	0.1461	8	19	42800	20000	0.0196	0.831	12	25.0	98.6
206	0.1461	0.1461	8	19	42800	20000	0.0196	0.831	12	25.0	98.6
207	0.1461	0.1461	8	19	42800	20000	0.0196	0.827	12	25.0	98.6
208	0.1461	0.1461	8	19	42800	20000	0.0196	0.827	11	25.0	98.6

ENGINE CONFIGURATION AND AMBIENT CONDITIONS

RUN #	BORE (m)	STROK (m)	# CYL.	COMP. RATIO	LHV DF2 (kJ/kg)	LHV TEST FUEL (kJ/kg)	ENG. DISP. (m3)	CHARG EFFIC.	RH (%)	AMB. TEM (DEG. C)	BARO (kPa)
209	0.1461	0.1461	8	19	42800	20000	0.0196	0.834	11	25.0	98.6
210	0.1461	0.1461	8	19	42800	20000	0.0196	0.833	11	25.0	98.6
211	0.1461	0.1461	8	19	42800	20000	0.0196	0.833	11	25.0	98.6
212	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	11	25.0	98.6
213	0.1461	0.1461	8	19	42800	14500	0.0196	0.834	11	23.9	98.7
214	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	11	25.6	98.8
215	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	11	25.6	98.6
216	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	11	25.6	98.6
217	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	11	25.6	98.6
218	0.1461	0.1461	8	19	42800	20000	0.0196	0.833	17	19.5	98.8
219	0.1461	0.1461	8	19	42800	20000	0.0196	0.833	18	19.5	98.8
221	0.1461	0.1461	8	19	42800	20000	0.0196	0.832	37	27.2	98.0
222	0.1461	0.1461	8	19	42800	20000	0.0196	0.833	37	27.2	98.0
223	0.1461	0.1461	8	19	42800	20000	0.0196	0.834	49	25.0	97.8
224	0.1461	0.1461	8	19	42800	0	0.0196	0.834	40	10.6	98.5
225	0.1461	0.1461	8	19	42800	0	0.0196	0.834	39	11.1	98.5
226	0.1461	0.1461	8	19	42800	20000	0.0196	0.831	37	10.6	98.5
227	0.1461	0.1461	8	19	42800	20000	0.0196	0.831	36	10.6	98.5
228	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	36	11.1	98.6
229	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	36	11.1	98.6
230	0.1461	0.1461	8	19	42800	14500	0.0196	0.815	4	11.1	92.8
231	0.1461	0.1461	8	19	42800	14500	0.0196	0.829	37	11.1	98.6
232	0.1461	0.1461	8	19	42800	14500	0.0196	0.828	36	11.7	98.6
233	0.1461	0.1461	8	19	42800	14500	0.0196	0.825	35	11.7	98.6
234	0.1461	0.1461	8	19	42800	14500	0.0196	0.827	35	11.7	98.6
235	0.1461	0.1461	8	19	42800	14500	0.0196	0.827	36	12.2	98.6
236	0.1461	0.1461	8	19	42800	20000	0.0196	0.830	27	13.9	98.6
237	0.1461	0.1461	8	19	42800	20000	0.0196	0.831	26	13.9	98.6
238	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	26	15.0	98.6
239	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	24	14.5	98.6
240	0.1461	0.1461	8	19	42800	14500	0.0196	0.817	24	14.5	92.8
241	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	24	13.9	98.6
242	0.1461	0.1461	8	19	42800	14500	0.0196	0.829	24	14.5	98.6
243	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	24	14.5	98.6
244	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	24	15.0	98.6
245	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	24	14.5	98.6
246	0.1461	0.1461	8	19	42800	0	0.0196	0.796	59	18.3	98.7
247	0.1461	0.1461	8	19	42800	20000	0.0196	0.780	17	19.5	93.0
248	0.1461	0.1461	8	19	42800	15600	0.0196	0.798	44	20.0	98.8
249	0.1461	0.1461	8	19	42800	15600	0.0196	0.797	43	20.6	98.8
250	0.1461	0.1461	8	19	42800	15600	0.0196	0.795	39	20.6	98.8
251	0.1461	0.1461	8	19	42800	15600	0.0196	0.795	38	20.6	98.8
252	0.1461	0.1461	8	19	42800	15600	0.0196	0.795	31	20.6	98.8
253	0.1461	0.1461	8	19	42800	15600	0.0196	0.796	29	20.6	98.8
254	0.1461	0.1461	8	19	42800	0	0.0196	0.799	12	25.0	98.9
255	0.1461	0.1461	8	19	42800	20000	0.0196	0.796	13	23.9	98.9
256	0.1461	0.1461	8	19	42800	20000	0.0196	0.796	13	23.3	98.9
257	0.1461	0.1461	8	19	42800	15600	0.0196	0.795	13	24.5	98.9
258	0.1461	0.1461	8	19	42800	15600	0.0196	0.795	13	25.0	98.8
259	0.1461	0.1461	8	19	42800	15600	0.0196	0.796	13	24.5	98.9
260	0.1461	0.1461	8	19	42800	15600	0.0196	0.795	13	25.6	98.9
261	0.1461	0.1461	8	19	42800	15600	0.0196	0.798	13	25.0	98.8

ENGINE CONFIGURATION AND AMBIENT CONDITIONS

RUN #	BORE (m)	STROK (m)	# CYL.	COMP. RATIO	LHV DF2 (kJ/kg)	LHV TEST FUEL (kJ/kg)	ENG. DISP. (m3)	CHARG EFFIC.	RH (%)	AMB. TEM (DEG. C)	BARO (kPa)
262	0.1461	0.1461	8	19	42800	15600	0.0196	0.793	13	26.7	98.9
263	0.1461	0.1461	8	19	42800	15600	0.0196	0.798	12	26.1	98.9
264	0.1461	0.1461	8	19	42800	0	0.0196	0.799	10	26.7	99.6
265	0.1461	0.1461	8	19	42800	20000	0.0196	0.795	10	27.2	99.6
266	0.1461	0.1461	8	19	42800	0	0.0196	0.796	22	28.3	98.0
267	0.1461	0.1461	8	19	42800	0	0.0196	0.797	11	28.3	99.2
268	0.1461	0.1461	8	19	42800	20000	0.0196	0.797	11	27.8	99.2
269	0.1461	0.1461	8	19	42800	0	0.0196	0.837	10	28.9	99.1
270	0.1461	0.1461	8	19	42800	20000	0.0196	0.834	10	30.0	99.1
271	0.1461	0.1461	8	19	42800	14500	0.0196	0.834	10	28.9	99.1
272	0.1461	0.1461	8	19	42800	14500	0.0196	0.833	10	30.0	99.1
273	0.1461	0.1461	8	19	42800	14500	0.0196	0.833	9	30.6	99.1
274	0.1461	0.1461	8	19	42800	0	0.0196	0.800	9	30.0	99.1
275	0.1461	0.1461	8	19	42800	20000	0.0196	0.798	9	31.7	99.1
276	0.1461	0.1461	8	19	42800	20000	0.0196	0.831	9	31.1	99.1
277	0.1461	0.1461	8	19	42800	0	0.0196	0.795	29	26.7	98.8
278	0.1461	0.1461	8	19	42800	20000	0.0196	0.795	29	26.1	98.7
279	0.1461	0.1461	8	19	42800	0	0.0196	0.834	28	27.2	98.7
280	0.1461	0.1461	8	19	42800	20000	0.0196	0.832	29	27.2	98.7
281	0.1461	0.1461	8	19	42800	14500	0.0196	0.833	30	26.7	98.7
282	0.1461	0.1461	8	19	42800	14500	0.0196	0.834	31	26.1	98.7
283	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	32	26.1	98.7
284	0.1461	0.1461	8	19	42800	14500	0.0196	0.833	32	25.6	98.7
285	0.1461	0.1461	8	19	42800	0	0.0196	0.837	32	26.1	98.7
286	0.1461	0.1461	8	19	42800	20000	0.0196	0.832	32	25.6	98.7
287	0.1461	0.1461	8	19	42800	19500	0.0196	0.833	32	26.1	98.7
288	0.1461	0.1461	8	19	42800	19500	0.0196	0.835	33	25.6	98.7
289	0.1461	0.1461	8	19	42800	19500	0.0196	0.831	32	25.6	98.7
290	0.1461	0.1461	8	19	42800	19500	0.0196	0.832	34	25.0	98.7
291	0.1461	0.1461	8	19	42800	19500	0.0196	0.831	34	25.6	98.7
292	0.1461	0.1461	8	19	42800	19500	0.0196	0.833	35	25.0	98.7
293	0.1461	0.1461	8	19	42800	19500	0.0196	0.833	35	25.0	98.7
294	0.1461	0.1461	8	19	42800	19500	0.0196	0.833	34	24.5	98.7
295	0.1461	0.1461	8	19	42800	19500	0.0196	0.833	36	25.0	98.7
296	0.1461	0.1461	8	19	42800	19500	0.0196	0.833	36	25.0	98.7
297	0.1461	0.1461	8	19	42800	0	0.0196	0.834	64	20.6	98.7
298	0.1461	0.1461	8	19	42800	20000	0.0196	0.830	65	20.0	98.7
299	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	63	20.6	98.8
300	0.1461	0.1461	8	19	42800	14500	0.0196	0.835	63	19.5	98.8
301	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	63	18.9	98.7
302	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	71	18.9	98.7
303	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	71	18.9	98.7
304	0.1461	0.1461	8	19	42800	14500	0.0196	0.833	71	18.9	98.7
305	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	71	18.9	98.7
306	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	73	18.9	98.7
307	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	74	18.9	98.7
308	0.1461	0.1461	8	19	42800	14500	0.0196	0.829	77	18.3	98.7
309	0.1461	0.1461	8	19	42800	14500	0.0196	0.829	78	19.5	98.7
310	0.1461	0.1461	8	19	42800	14500	0.0196	0.829	74	20.0	98.7
311	0.1461	0.1461	8	19	42800	14500	0.0196	0.832	72	19.5	98.7
312	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	70	18.9	98.7
313	0.1461	0.1461	8	19	42800	14500	0.0196	0.831	70	18.9	98.7

ENGINE CONFIGURATION AND AMBIENT CONDITIONS

RUN #	BORE (m)	STROK (m)	# CYL.	COMP. RATIO	LHV DF2 (kJ/kg)	LHV TEST FUEL (kJ/kg)	ENG. DISP. (m3)	CHARG EFFIC.	RH (%)	AMB. TEM (DEG. C)	BARO (kPa)
314	0.1461	0.1461	8	19	42800	14500	0.0196	0.834	72	19.5	98.7
315	0.1461	0.1461	8	19	42800	14500	0.0196	0.830	70	20.0	98.7
316	0.1461	0.1461	8	19	42800	0	0.0196	0.832	63	21.1	98.6
317	0.1461	0.1461	8	19	42800	20000	0.0196	0.828	64	20.6	98.6
318	0.1461	0.1461	8	19	42800	19500	0.0196	0.829	65	20.6	98.6
319	0.1461	0.1461	8	19	42800	19500	0.0196	0.829	65	20.6	98.6
320	0.1461	0.1461	8	19	42800	19500	0.0196	0.830	66	20.0	98.5
321	0.1461	0.1461	8	19	42800	19500	0.0196	0.829	67	20.0	98.5
322	0.1461	0.1461	8	19	42800	19500	0.0196	0.828	69	20.0	98.4
323	0.1461	0.1461	8	19	42800	19500	0.0196	0.828	69	20.0	98.4
324	0.1461	0.1461	8	19	42800	19500	0.0196	0.831	70	20.0	98.4
325	0.1461	0.1461	8	19	42800	19500	0.0196	0.828	70	20.0	98.4
326	0.1461	0.1461	8	19	42800	19500	0.0196	0.828	71	20.0	98.4
327	0.1461	0.1461	8	19	42800	19500	0.0196	0.825	71	20.0	98.4
328	0.1461	0.1461	8	19	42800	19500	0.0196	0.827	71	20.0	98.4
329	0.1461	0.1461	8	19	42800	19500	0.0196	0.827	70	20.0	98.4
330	0.1461	0.1461	8	19	42800	20000	0.0196	0.833	38	31.7	98.5
331	0.1461	0.1461	8	19	42800	20000	0.0196	0.834	38	31.7	98.5
332	0.1461	0.1461	8	19	42800	27600	0.0196	0.892	15	35.0	93.2
333	0.1461	0.1461	8	19	42800	27600	0.0196	0.895	32	35.0	98.4
334	0.1461	0.1461	8	19	42800	27600	0.0196	0.903	32	35.0	98.4
335	0.1461	0.1461	8	19	42800	27600	0.0196	0.903	31	35.0	98.4
336	0.1461	0.1461	8	19	42800	14500	0.0196	0.903	31	35.6	98.4
337	0.1461	0.1461	8	19	42800	14500	0.0196	0.903	31	35.6	98.4
338	0.1461	0.1461	8	19	42800	14500	0.0196	0.901	30	35.0	98.4
339	0.1461	0.1461	8	19	42800	14500	0.0196	0.901	31	35.0	98.4
340	0.1461	0.1461	8	19	42800	14500	0.0196	0.901	32	35.0	98.4

APPENDIX F

Photographs of Filter Samples For Combustion Efficiency Measurements

Runs 228 and 229

0.0044 kg/s Flow of Otisca Slurry With 25° BTDC Injection Timing

Runs 230 and 231

0.0071 kg/s Flow of Otisca Slurry With 25° BTDC Injection Timing

Runs 232 and 233

0.0089 kg/s Flow of Otisca Slurry With 25° BTDC Injection Timing

Runs 234 and 235

0.0094 kg/s Flow of Otisca Slurry With 25° BTDC Injection Timing

Runs 238 and 239
0.0058 kg/s Flow of Otisca Slurry With 20° BTDC Injection Timing

Runs 240 and 242
0.0070 kg/s Flow of Otisca Slurry With 20° BTDC Injection Timing

Runs 242 and 243

0.0086 kg/s Flow of Otisca Slurry With 20° BTDC Injection Timing

Runs 244 and 245

0.0058 kg/s Flow of Otisca Slurry With 20° BTDC Injection Timing

**DATE
FILMED**

4/26/94

END