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Texas Commission on Environmental Quality
New Technology Research & Development (NTRD) Program
Final Project Report
Railpower RP-20BH Hybrid Road Switching Locomotive

Contract Number: ___582-5-70807-0012 _____

Grantee: _Railpower Hybrid Technologies Corporation_____

Date Submitted: _____01/19/2007_____

Final Report:

Program Overview - RP20BH Locomotive

The Railpower RP20BH locomotive is a market driven extension of the GG20B Yard Switching locomotive designed for yard switching duty as well as typical road switching function all while maximizing fuel efficiency and emissions reduction. It employs similar technology as the GG20B yard switcher utilizing large battery cells and low emissions engines with integral alternators and cooling systems in the form of a generator set.

The need for the multiple engine design came from the inherent limitations surrounding extensive use of batteries as the prime mover. The GG20B equipped with a single 100kW generator set, as originally designed, ran successfully on all yard flat switching operations. Typically, the locomotive would operate for 20-30 minutes on battery alone, then run as a true hybrid with the engine being assisted by battery power as necessary. In light duty cycles, the engine would recharge the battery while the loco was in operation, and turn off when the battery was recharged, and the cycle would repeat. In heavier duty cycles the average battery state of charge would stay relatively constant (average work load of the locomotive for traction and auxiliaries being about 70 kW) and the engine would run for 20-30 minutes during the crew break, lunch break, waiting periods, or at the end of shift. In the odd extremely heavy duty cycle, the state of charge would decrease temporarily, and may produce the need to shut down the locomotive. For these reasons, the production version of the GG20B was equipped with a slightly larger engine, 200 kW. This would allow the engine to supply more power without the battery. This would be helpful particularly when transferring cuts of cars from one part of the yard to another. For example, as a locomotive accelerates to 6 mph with a given tonnage, the power will increase with speed to a peak of approximately 800 kW. Once the loco stops accelerating the power requirement is much less to maintain speed, typically 100-200 kW. 200 kW is sufficient to maintain modest speed (5-10 mph) depending on tonnage, track curvature and grades. The grades must necessarily be very short, or extremely shallow (less than 0.5%).

After reviewing event recorder data (see discussion in section 2.1.1) it is immediately apparent that the ratio of average power to peak power will be higher in a road switcher, and the drive cycle will include much more sustained intervals at higher power levels. This suggests a milder hybrid, or a lower degree of hybridization. In many cases, the driving pattern, and thus the power requirements are very similar to that of the yard switcher. There are a couple of small differences: a road switcher is more likely to be spotting cars at industrial warehouses. This means that the engineer will use the brakes and apply power simultaneously to keep the train stretched out or compressed for precise positioning. Also the engineer may need to drive a cut of cars to an industrial location that is at significantly lower grade than the track grade. In this case he will apply brakes and drive against the brakes all the way down to the spotting location. In addition to this low-speed/low average-power work, there is usually a component of the drive

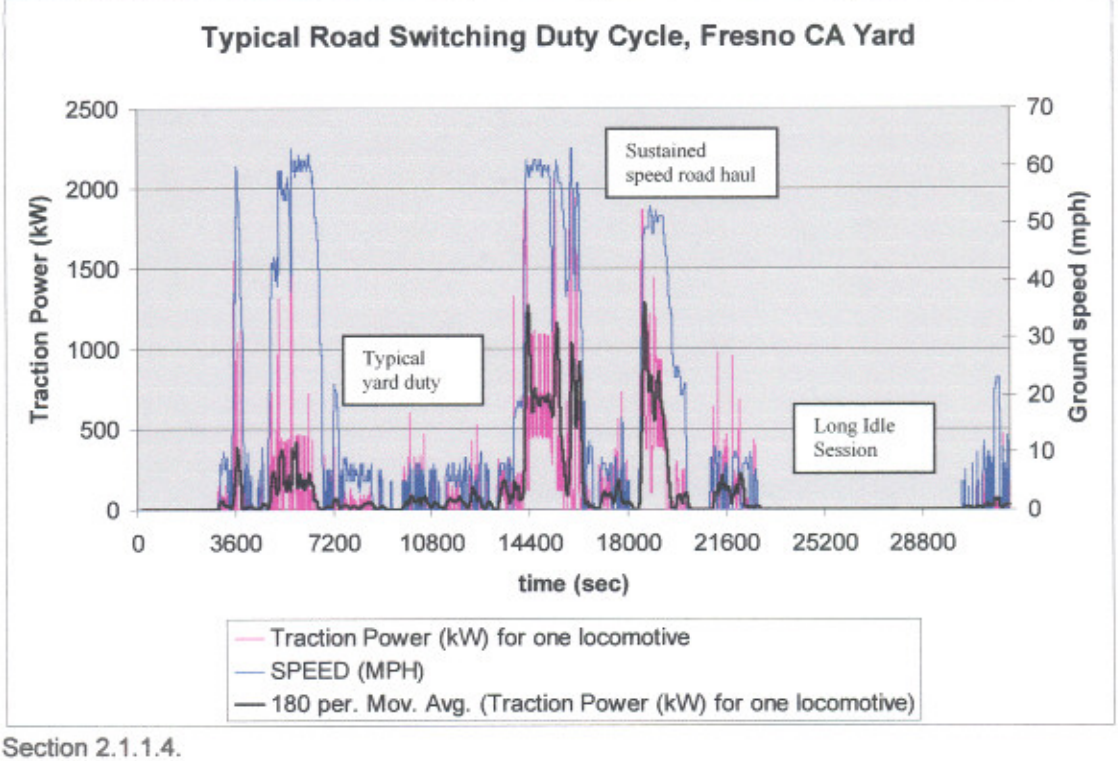
cycle where the loco is transferring the cars from a main yard to the remote industrial location, typically from 10 to 50 miles distant. Given an existing road switcher such as the EMD GP38, the transfer can be done with moderate tonnage at speeds of 30-50 mph. Alternatively the transfers are carried out with more tonnage at lower speeds, as in the UP Houston area. In this case, the cars are transferred from a main yard to an industrial park, separated into smaller cuts, then deliveries made to customers in the region. The RP20BH is well positioned to handle the complex driving cycle, consisting of these two distinct components. In the slow speed work, the BH could operate with one engine (at variable speed), depending on traction requirements and battery state of charge. In the transfer mode, the two engines can operate in tandem to provide continuous (approx.) 1500 HP capability.

Task 1 - Definition of Requirements and Preliminary design

Section 2.1.1. (1.- 3.)

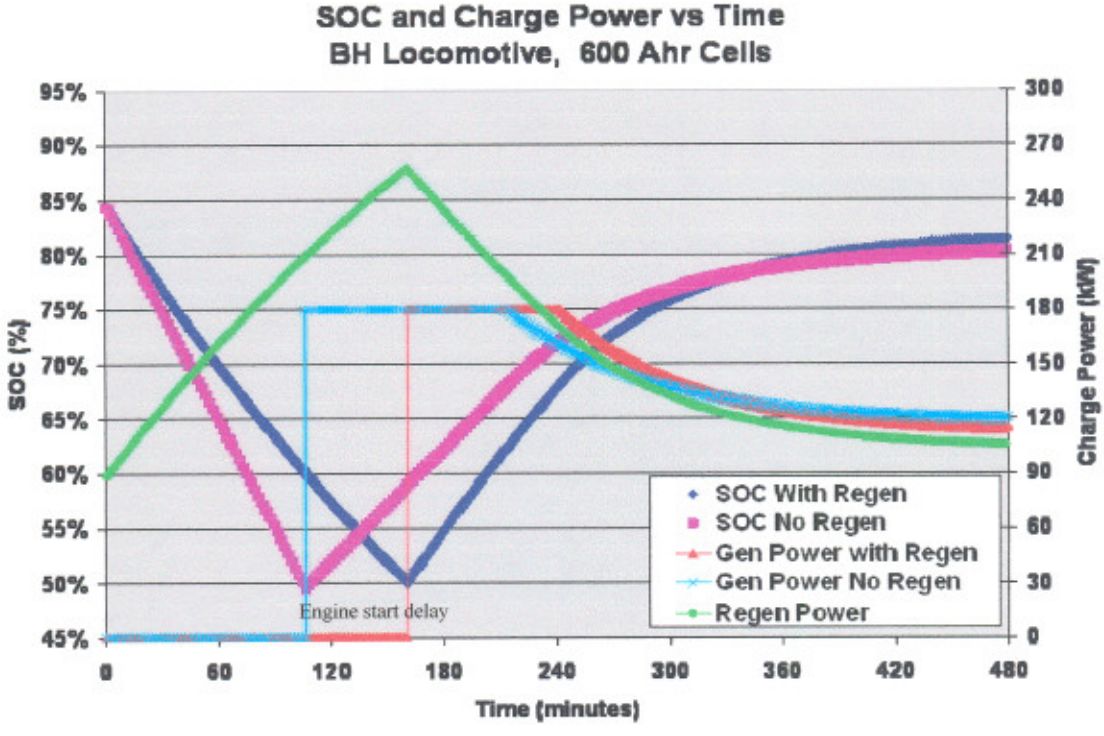
Railpower has cooperated with interested railroads (predominately UP) and collected a substantial amount of data from the locomotive event recorder from different rail yards, different locomotives used in typical road switching service on different shifts. All data is available upon request but this report shall discuss typical findings of Railpower in regards to tractive power required, notch position, ground speed and dynamic brake power.

The figure below shows a typical duty cycle for a road switching locomotive used in the Fresno, CA area by Union Pacific. Labeled on the figure are the clear distinctions between the idle rest portions, typical yard switching portions and typical road switching portions as discussed previously. The data suggest a perfect application for a RP20BH locomotive. The longer, sustained higher speed application defines the need for a multiple engine approach, the larger sections of typical yard switching duty fit well with the hybrid model of the GG20B locomotive and the sustained periods of idle for this particular locomotive will emphasize the fuel and emissions savings of the Railpower RP20BH design.



Section 2.1.1.4.

The chart below shows some analysis conducted by Railpower for the BH locomotive in a worst case scenario, operating continuously for a full eight hour shift. The figure shows the charge power from the generator set as well as the contribution of regenerative braking. The chart shows two main points. First, recapturing energy from regenerative braking will delay the point where the generator set is started. Secondly, the use of regenerative braking will reduce the load on the generator set while operating to maintain a specific state of charge for the battery cells. Both of these advantages will save fuel. However, there are drawbacks with the use of regenerative braking. If the batteries are at a high state of charge and the locomotive is equipped with regenerative braking, grid resistors will still be required. The batteries cannot accept charge energy from the regenerative braking and that energy must be sent to a resistor bank. The economics surrounding the use of regenerative braking warrants further investigation.



Section 2.1.2

Following the requirements for prime mover power requirements several engine manufacturers were evaluated. The final selection considered the Deutz TCB2015 and the Cummins QSX 15 engine. Below is a table of comparative features for these two engines in this prime mover application.

	Cummins QSX 15	Deutz TCB2015
Engine Classification	Industrial	Truck
Engine Model	QSX 15 liter	TCD 2015 15.87 liters
Cylinders	6	8
Cylinder Arrangement	In-line	90 V
Displacement	15 Liters	15.87 liters
Compression Ratio	17.0:1	17.5:1
Bore and Stroke	5.4in x 6.7in	5.2in x 5.7in
Aspiration	Turbocharged, Charged Air Cooled	Turbocharged, after cooler
Continuous Horsepower	510	544
Peak Torque @ RPM	1569 lb-ft @ 1400 RPM	2129.9 lb-ft @ 1400 RPM
Inlet Air Flow	1569 ft^3/min	1566 ft^3/min
Maximum Exhaust Back Pressure	10.1 kPa	7.5 kPa
Engine EPA Certification Level	EPA Off-Road Tier III	EPA Off-Road Tier III
Notch 8 Traction HP Rating (3 Gensets)	1453	1508
Notch 8 Traction HP Rating (1 Genset)	484	503
Notch 8 Rating - Continuous HP Rating	Continuous	Continuous
Notch 8 Engine HP as a % Continuous	95.00%	93.78%
Length	59.2in	57.2in
Width	37.7in	50.8in
Height	51.1in	32.9in
BSFC in Gallons/Net - Traction HP Hour	0.049	0.053
EPA NOx Rating in Grams PBHPHR	2.98	3.9
EPA PM Rating in Grams PBHPHR	0.149	0.1
Engine Operation Hours to Recommended Overhaul	16500 estimate	10000-12000
Injector Life in Hours Before Scheduled Replacements	10000 estimate	7000
Turbocharger Life in Hours Before Scheduled Replacement	20000 estimate	15000
Engine Sump Oil Change Cycles in Hours	1500+	1000
Fuel Injections Technology	Modular Common Rail and EFI	Individual Pump Electronic Injection System
After Treatment Use	Particulate Device within Muffler Envelope	None at this time

The Deutz engine was chosen on three primary features: higher continuous horsepower rating, smaller overall footprint and total generator set package cost. Following the engine selection, Railpower jointly developed a generator set package with the selected supplier, Stauffer Diesel, for use on the RP-20BH engine. Stauffer Diesel has been successfully

supplying smaller generator set packages to the transit rail business for several years. The full details of that generator set package are summarized in the attachment titled RP50006 Rev 1 Date 0304

2.1.2.2 Preliminary Design

Once the weight and overall dimensions of the generator set had been selected as well as that for the battery cells and battery support structure a preliminary design for the RP20BH was completed. The target market for the BH application would be for retrofit of GP38 and GP40 locomotives originally designed by EMD as well as B23 and Dash-7 locomotives originally design by General Electric. The original BH design is defined by Railpower drawing RP-04897 LOCATION OF APPARATUS RP20BH ON GE PLATFORM is attached for reference.

2.1.2.3 Suppliers for engine hoods and cabs

Railpower has used two main suppliers in the past for operator cabs, Super Steel Products Corporation in Milwaukee, WI as well as Motive Power Inc. in Boise, ID. For the BH prototype program Railpower used an operator cab supplied by Motive Power Inc. All engine hoods were supplied by Super Steel Products Inc.

Task 2 - Detailed design and construction

Once the design process is started all design specifications and drawings are captured on a document titled a locomotive list. Railpower has created this document with document number RP-L0007G100. This document is also attached to this report.

2.2.1.1 Railpower had identified a "hulk" locomotive to be used for this project. Originally owned by Canadian National with road number 9637, the unit was purchased by Railpower and transferred to Alstom Transport Services for teardown.

2.2.1.3 Purchase of long lead items

Railpower has purchased the following list of major components from the referenced supplier to support the completion of the RP20BH prototype build. Also included are the suppliers who stripped the "hulk" locomotive and prepared the balance of the components.

Item/Work Scope	Supplier	Location
Core strip and preparation	Alstom Transport Services	Calgary, AB, Canada
Platform preparation	Super Steel Schenectady Inc.	Schenectady, NY
Operator Cab	Motive Power Inc.	Boise, ID
Batteries	Leoch Power Inc.	China
Battery Rack Structure	Super Steel Products Corp	Milwaukee, WI
Air Compressor	Air Plus Systems	Burnaby, B.C., Canada
Generator Set	Stauffer Diesel/Stadco	Ephrata, PA
High Voltage Compartment	Liberty Electronics	Franklin, PA
Engine Hood	Super Steel Products Corp	Milwaukee, WI
Rear Nose	JP Metals Inc.	Calgary, AB, Canada
Final Assembly/Test	Super Steel Schenectady Inc.	Schenectady, NY

2.2.2 Assemble of Components

Following the design process, all parts were procured and assembled at our Super Steel plant in Schenectady, New York into the completed locomotive. The attached photograph shows the unit with assigned road umber 5401.

Task 3 – Certification Testing

Section 2.3.1.1.

Since the RP20BH unit did not travel under its own power to the testing site in San Antonio, Texas, independent Railroad insurance in Railpower's name was not needed for the unit as the unit was insured by the delivering transporter.

Section 2.3.1.2

The RP20BH is designed to have the capability to monitor and/or record the estimated fuel consumption, tractive energy output, notch position, engine run time, generator kW hours.

Section 2.3.3. Due to the **sensitive and confidential** nature of the information, the following documents have been attached as separate documents: SwRI emissions testing report; Parts List - RP-L0007G100_G; Genset Info - RP50006 REV 01 Date 0304; Schematic Drawing - RP-04897_A.

_____ Date:____*01/19/07*_____

Authorized Project Representative's Signature

NOTE: *Please attach any additional information that you feel should be a part of your report or that may be required to meet the deliverable requirements for tasks completed during this reporting period.*

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

2006 Model Year Certificate of Conformity

Manufacturer: **RailPower Hybrid Technologies, Corp.**
Certificate Number: RHT-LOC-06-02
Effective Date: MAR 14 2006
Date Issued: MAR 14 2006

Karl J. Simon
Acting Director
Compliance and Innovative Strategies Division

Pursuant to Section 213 of the Clean Air Act (42 U.S.C. section 7547) and 40 CFR 92, and subject to the terms and conditions prescribed in those provisions, this certificate of conformity is hereby issued with respect to the remanufacturing kit which has been found to conform to applicable requirements and which may be utilized with only the following locomotive engines, by engine family, more fully described in the documentation required by 40 CFR 92 and produced in the stated model year.

Locomotive Engine Family (Remanufacturing Kit): 6RHTK0121BH1
Locomotive Models: (Models which apperar to be duplicates are part of a different engine model/locomotive model combination.)

RP20BH

Locomotive Model Years: 1960 to 1985 The rebuild kit includes:

ALL PARTS ABOVE PLATFORM

In addition, parties who install this remanufacturing kit must also ensure that the base engine contains the following parts, more fully described in the Application for Certification for this kit:

PLATFORM, AND EVERYTHING BELOW IT

This certificate of conformity is conditional upon compliance of said manufacturer with the provisions of 40 CFR Part 92, Subpart D. Failure to comply with these provisions may render this certificate void ab initio.

Locomotive Engines

Perform Quick Check | Send Records to Database | Save File | Delete All Template Records | Print

Template - - Application Forms

View Database | Add New Engine Record

Family: **6RHTK0121BH1**

General Info | Characteristics | AECD's etc. | Tech descrip. | Statement of Compliance

Test Info | Parts Info | Model Info

11/14/05
2/27/06

1. Manufacturer: RailPower Hybrid Technologies, Corp.

2. Certification Contact: first name: Scott last name: Carpenter

3. Certification Contact Person's, address, phone, etc.:

& street: 2021 Peninsula Drive
address:
address:
city: Erie state: PA zip: 16506
phone: (512) 260-9461 office fax: (512) 260-9744 fax email: scarpenter@railpower.com

4. Locomotive Category: Reman Tier: 0

5. Certification Type: Locomotive

Items included in kit if Reman:

Parts which must be present on the engine when installing a kit

1960 to 1985

6. Model Year: 2006

7a. Carryover: ○ Yes ◉ No

7b. If yes, carried over from (engine family):

8. Process Code: New Submission

If RC or corr, describe:

Date EPA fee paid: 12/16/2005

9. EPA Engine Family: 6RHTK0121BH1

10. Mfr. Family Name: RP20BH

11. Plant Location

ALSTOM Locomotive Facility
7550 Ogdendale Road, SE
Calgary, AB T2C 4X9
Canada

12. Plant Contact

Mr. Randy George

NEXT PAGE Characteristics

Locomotive Engines

Template - - Application Forms

Family: **6RHTK0121BH1**

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View Database | Add New Engine Record

General Info | Characteristics | AECD's etc. | Tech descrip. | Statement of Complianc

Test Info | Parts Info | Model Info

11/14/05
2/27/06

13. Displacement/cylinder: 121
Engine configuration (I6,V8,etc): V8

14. Displacement units: cubic inches

15. Emission Control System
- [ ] Catalyst
- [ ] Engine Modification
- [ ] Electronic Control
- [x] Smoke Puff Limiter
- [ ] EGR (Exhaust Gas Recirculation)
- [ ] None
- [ ] Other...

16. Projected Sales - 50St: 1

17. Estimated Production Period
a. Begin: 3/1/2006
b. End: 12/31/2006

c. Date of Introduction into Commerce: 3/1/2006

18. Fuel Type: Diesel

19. Useful life

Loc #1	Useful Life	15,750	Megawatts and	10	Year
	Useful Life		Miles and		Year
Loc #2	Useful Life		Megawatts and		Year
	Useful Life		Miles and		Year
Loc #3	Useful Life		Megawatts and		Year
	Useful Life		Miles and		Year
Loc #4	Useful Life		Megawatts and		Year
	Useful Life		Miles and		Year
Loc #5	Useful Life		Megawatts and		Year
	Useful Life		Miles and		Year

20. Fuel System Type: Direct Injection

21. Deterioration Factor Type:

	Gaseous	Smoke
Additive	◉	◉
Multiplicative	○	○

22. Aspiration: Turbo Air to Air (TAA)

23. Service Class: ◉ Switch ○ Line Haul ○ Passenger

24. program information

averaging			banking and trading		
switch	line haul	pass.	switch	line haul	pass.
☒ PM	☐ PM		☒ PM	☐ PM	

25. FEL — Leave blank if you checked None in # 24.

	Switch	Line Haul
PM	0.19	
NOx	4.7	

☒ NOx	☐ NOx	☒ NOx	☐ NOx
☐ None	☒ None	☐ None	☒ None

FEL units

26. Alternate CO/PM Standards ○ Yes ◉ No

NEXT PAGE AECD's, etc.

Locomotive Engines

Template - - Application Forms

Family: **6RHTK0121BH1**

Perform Quick Check | Send Records to Database | Save File | Delete All Template Records | Print

View Database | Add New Engine Record

General Info | Characteristics | AECD's etc. | Tech descrip | Statement of Compliance

Test Info | Parts Info | Model Info | 11/14/05 | 2/27/06 | MENU

27. Auxiliary Emission Control Devices

	AECD:	Sensed parameters:	Controlled parameters:	Does AECI reducing effe emission cont
1				Yes
2				Yes
3				Yes
4				Yes
5				Yes
6				Yes
7				Yes
8				Yes
9				Yes
10				Yes
11				Yes
12				Yes
				Yes
				Yes

28. Adjustable Parameters:

Parameter	Adjustable Range (or N/A)	Tamper Resistance Method (or N/A)

NEXT PAGE Tech descrip.

Locomotive Engines

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Family: **6RHTK0121BH1**

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View Database | Add New Engine Record

General Info | Characteristics | AECD's etc. | Tech descrip. | Statement of Compliance

Test Info | Parts Info | Model Info

11/14/05

2/27/06

M E N U

29. Technical Description

Emission Control System: Two identical diesel engine generator sets that have been previously EPA certified to Part 89 Tier 2 non-road emission standards. Deutz engine model, BF8M1015CP, EPA engine family, 5DZXL15.9002 and engine code, D517/1. No other mechanical or electrical auxiliary emission control devices have been added.

Main Engine Description: The engine design for the Deutz model, BF8M1015CP, is a 90 degree V-8 cylinder, 121 cubic inch displacement per cylinder, (V-8 = 968 total cubic inches), four cycle (4 stroke), rated at 693 intermittent horsepower, (517kW), at 1800 rpm. The cylinders have a bore of 5.2 inches and a stroke of 5.7 inches with a compression ratio of 16.5:1. The engine has a mechanical fuel system with direct injection. These engines do not have any electronic control modules but are equipped with puff limiters. The combustion air is pressurized with a turbocharger and is aftercooled, (air-to-air). This locomotive will then have 16 total engine cylinders with a rating of 1600 total horsepower.

Locomotive Description: This locomotive is manufactured from older existing units. Everything above the existing platform, (cabs, radiators, etc.), is removed and replaced with all new components. The existing platform and all components, (ex. trucks, traction motors,

30. Comments

Emissions Data and Testing: all test data presented in this application was provided by Southwest Research Institute's locomotive test facility in San Antonio Texas. Two FTP tests were run to demonstrate the consistency of the test data with the locomotive batteries at a high state-of-charge and a low state-of-charge.

Second Assembly Facility: Mr. Todd Thelen, Operations Manager, Super Steel Schenectady, Inc., 2000 Seventh Street, Glenville, NY 12302.

31. Maintenance instructions
(Right-click > Insert Object)

32. Graphic objects or other objects

Locomotive Engines

Template - - Application Forms

Family: **6RHTK0121BH1**

Perform Quick Check | Send Records to Database | Save File | Delete All Template Records | Print

View Database | Add New Engine Record

General Info | Characteristics | ABT's etc. | Tech descrip. | Statement of Compliance

Test Info | Parts Info | Model Info

11/14/05 | 2/27/06

Eng model	Loc Model	Inj pump	Injector	Turbocharger	Elec control module
BF8M1015CP	RP20BH	PE8P120A320LS7859P	DLLA158P1118	S300-066W	

Test Info | Parts Info | Models Info | 11/14/05 | 2/27/06

Eng model	Loc Model	Max HP	Rated speed	Fuel rate @ max power (lbs/hr)	Fuel rate @ max power (mm^3/str)
[illegible]	[illegible]	1800	1800	379	