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**New Technology Research & Development Program  
Grant Contract 582-5-70807-T033**

**Task 1 Deliverable Report  
Approved Test Plan**

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by the State of Texas through a Grant from the  
Texas Commission on Environmental Quality.



September 14, 2005

**TO:** TCEQ

**ATTN:** Kate Williams, and Joe Walton.

**Contract Number:** 582-5-70807-T033

**SUBJECT:** Proposed TCEQ Alternative Diesel Fuel Certification Testing Program for White Sands  
Proposed TCEQ Engine selection for White Sands

## **1.0. INTRODUCTION**

The purpose of this document is to provide a detailed engine test plan for TCEQ review prior to the start of an emissions test program

The Department of Engine and Emissions Research (DEER) at Southwest Research Institute® (SwRI®) has provided this test plan to White Sands LLC for emissions testing of a candidate fuel using a protocol specified by the Texas Commission on Environmental Quality (TCEQ) Chapter 114 – Control of Air Pollution From Motor Vehicles, Subchapter H: Low Emission Fuels, Division 2: Low Emission Diesel. The protocol is based on transient emission measurement procedures developed by the EPA for emissions regulatory purposes. The TCEQ protocol allows a 1991 Detroit Diesel Corp. Series 60 to be used as the "test bench" for comparing engine emissions using a reference fuel, "Fuel R," and a candidate fuel, "Fuel C." The TCEQ protocol requires that fuel evaluations be conducted using either several cold- and hot-start transient test sequences or several hot-start transient tests alone using one of five "alternative" test sequences.

## **2.0 STATEMENT OF WORK**

A reference fuel, Fuel R, and White Sands LLC candidate fuel, Fuel C have been selected that meet TCEQ §114.314 "Approved Test Methods" fuel specifications. The first step in the process is to show that the candidate fuel meets the requirements of the American Society of Testing and Materials (ASTM) D975.

SwRI proposes to use "Alternative 3" of the TCEQ procedure (four other test sequences are allowed by TCEQ). "Alternative 3" calls for consecutive hot-start testing of the fuels in the order of RRR CCC RRR CCC and continuing in the same order until a minimum of 21 individual hot-start emission tests have been completed with each fuel. Each average for a selected emission from a triplicate series of individual tests (i.e., RRR or CCC) is considered to be a single emission value for that fuel, to be used in statistically comparing the two fuels.



Emissions will be determined on each fuel include total hydrocarbons (THC), calculated NMHC, carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>), carbon dioxide (CO<sub>2</sub>), and total particulate matter (PM). The procedure given in Table 1 incorporates plans for instrument and sample system calibrations, changing fuels, determining engine performance, preparing and stabilizing emission measurement systems, and performing the transient test work to obtain the exhaust samples needed. Table 2 illustrates the pattern of 21 hot-start transient runs to be made on Fuel R and on Fuel C. On each of the 21 runs, THC, calculated NMHC, CO, NO<sub>x</sub>, PM, and CO<sub>2</sub> will be determined. Hot-start transient emission tests will be conducted as specified in the Code of Federal Regulations (CFR) Title 40, Part 86, Subpart N. Procedures for the measurement of THC, CO, NO<sub>x</sub>, CO<sub>2</sub>, and PM are described in Subpart N.

The test procedure outlined in Table 2 will require an estimated minimum of seven days and will also require an estimated minimum of 165 gallons of Fuel R and 160 gallons of Fuel C. In the event that repeat testing is required, it is important that additional quantities of test fuels be made available. In addition, emission measurement problems or engine problems can occur, requiring diagnostic efforts which generally can be run on in-house fuel; however, additional quantities of test fuel (20 gallons) should be allocated to ensure that there is enough fuel for an extra fuel change and emission run, if needed.



**TABLE 1. PROPOSED PROCEDURE FOR ACCUMULATING REGULATED EMISSIONS DATA USING ALTERNATIVE 3 OF THE TCEQ PROTOCOL**

Step	Description
1	Install engine. Perform emission instrument calibrations as required. Calibrate torquemeter and check signal conditioning systems. Validate CVS gaseous and particulate sampling systems using propane recovery techniques.
2	Check engine condition using in-house, low sulfur emissions type fuel, and note fault codes if any. Bring engine oil level to "full" using a manufacturer's recommended oil.
3	Perform fuel change procedure to operate on Fuel R. Change filter, purge fuel supply, etc.
4	Warm up engine and operate at rated speed and load, then check performance.
5	Conduct transient "full-throttle" torque map from low- to high-idle. Compute and store resulting transient command cycle. (Note: <u>This initial transient command cycle with Fuel R will be used for all subsequent emission tests in this test plan. Other torque-map information generated with either Fuels R or C during this test work will be stored for documentation purposes.</u> )
6	Run two 20-minute practice or conditioning transient cycles without a 20-minute soak between cycles, and adjust dynamometer controls to meet statistical limits for transient cycle operation
7	Soak the engine for 20-minutes. Run three hot-start transient tests with a 20-minute soak between each. For each individual hot-start test, determine THC, calculated NMHC, CO, NO <sub>x</sub> , CO <sub>2</sub> , and PM
8	Repeat Steps 3 through 7 with Fuel C.
9	On Day 2 of testing, repeat Steps 4 through 8 starting with Fuel C.
10	On Day 3 of testing, repeat Steps 4 through 8 starting with Fuel R.
11	On Day 4 of testing, repeat Steps 4 through 8 starting with Fuel C.
12	On Day 5 of testing, repeat Steps 4 through 8 starting with Fuel R.
13	On Day 6 of testing, repeat Steps 4 through 8 starting with Fuel C.
14	On Day 7 of testing, repeat Steps 4 through 8 starting with Fuel R.
15	Summarize data and prepare the final report.



**TABLE 2. PATTERN OF RUNS FOR FUEL R AND FUEL C OVER SEVEN DAYS USING “ALTERNATIVE 3”**

Test Day	Hot Start Transient							
	Fuel	Test Number			Fuel	Test Number		
1	R	1	2	3	C	4	5	6
2	C	7	8	9	R	10	11	12
3	R	13	14	15	C	16	17	18
4	C	19	20	21	R	22	23	24
5	R	25	26	27	C	28	29	30
6	C	31	32	33	R	34	35	36
7	R	37	38	39	C	40	41	42

The Series 60 test engine has been supplied by White Sands LLC, and is a rebuilt 1991, 12.7 liter, Series 60 engine. It is assumed that the rebuilt 1991 DDC Series 60 is suitable for this test work. This engine (S/N 06R0038671) is turbocharged and aftercooled. The Series 60 utilizes an electronic control module (ECM) or DDEC module to manage high-pressure fuel injection rate and timing according to the calibration that resides in the DDEC module for this engine. The calibration used with this engine results in a maximum power of 365 hp at a rated speed of 1800 rpm.



**TABLE 3. ENGINE DETAILS**

Engine sticker information

Serial # 06R0038671, Model # 6067GU60  
 Engine family MDD12.FZAX, Manufacturing date Jan 1991  
 Fuel rate at Adv HP 212.0 MM3/Stroke  
 Initial injection timing 18 Deg BTC  
 Conforms to Australian design rule 30 L11030  
 Not for usage in buses.

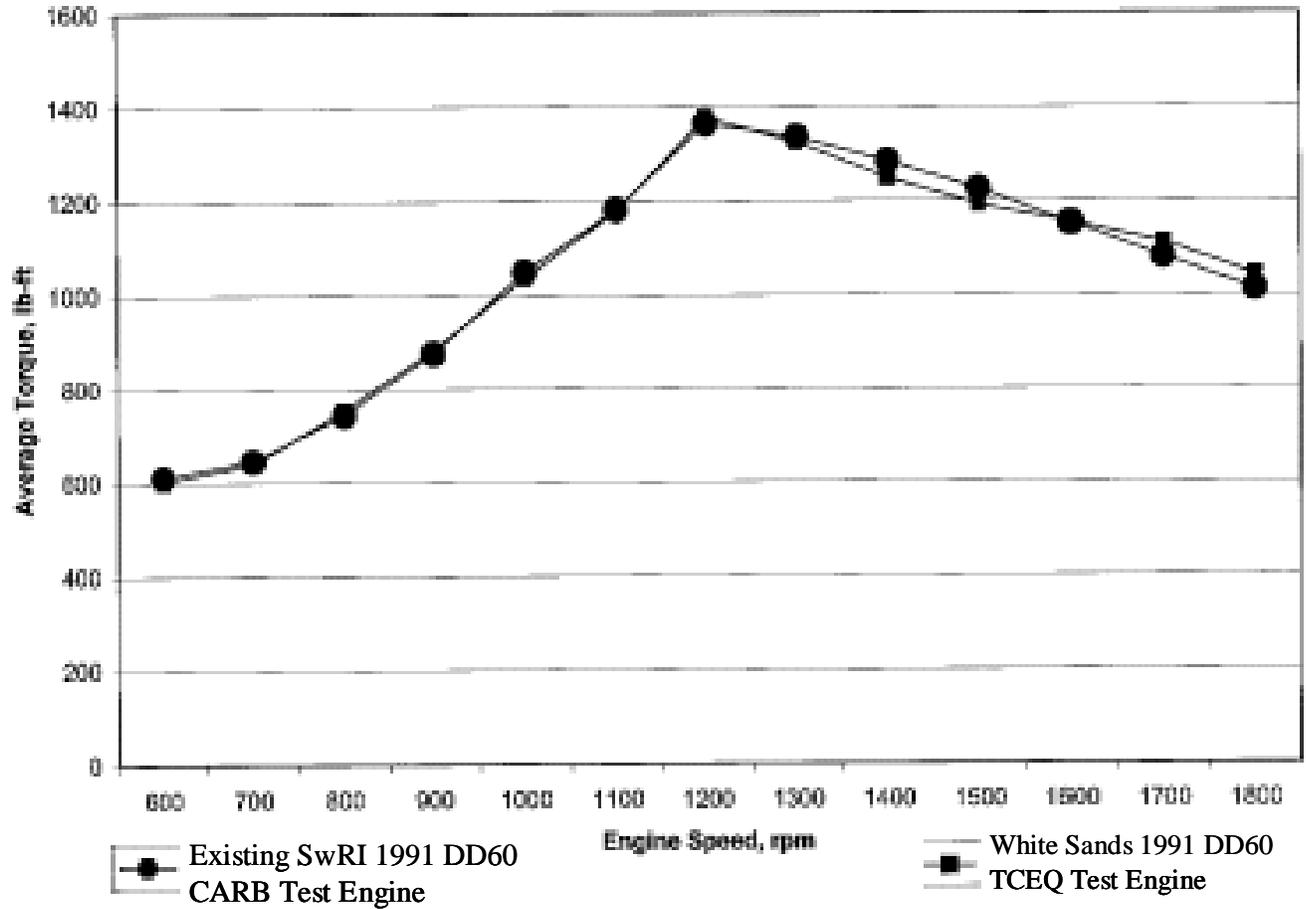
Overhaul parts list – all original 1991 parts sourced

Cam Shaft #23505195

Conn Rods:	Reconditioned	8929235
Block:	Complete remanufactured	
Crank:	Mag Polished STD:STD	8929289
Head:	Complete remanufactured	valve job, coppers, new valves, keepers, valve springs
Front Seal:		PN23518355
Turbo:	Rebuilt	PN23504966
Injectors:	DDA Exchange	PN R5234940
Oil Pump:	DDA Exchange	PN R23505886
Fuel Pump:	DDA Exchange	PN R3532981
Water Pump:	DDA Exchange	PN R23522707
Gasket Set:	O/H Gasket Set	23532332
Harness:	Inj. Harness	12114461
Harness:	Engine Harness	8929468
Cylinder Kits:	DDA New	R23532590
Low Bearing Set:	DDA New	PN 23531604
Cam Bearing:	DDA New	PN 8929690
T Stats:	DDA New	PN 2352436
SRS Sensor:	DDA New	8929387
TRS Sensor:	DDA New	8929388
Water Temp:	DDA New	23518092
Oil Pressure Sens:	DDA NEW	23532797
Module:	DDA New	23505265
Rear Seal:	DDA New	23516969
Oil Cooler:	Reconditioned	8547626
Air Comp:	Rebuilt Exchange	109425



**TABLE 4. ENGINE SPEED-TORQUE CURVE (THE “MAP”)**





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**TABLE 5. DETROIT DIESEL CERTIFICATION EMISSIONS**

09/07/05 WED 14:21 FAX 313 592 3892

DDC CORP DETROIT

001

**DETROIT DIESEL**

a DaimlerChrysler PowerSystems Company



**Facsimile / Telefax**

**To / An:** Brett Cristy Hanson  
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**Date / Datum:** September 7, 2005  
**No. of Pages / Seitenzahl:** 1

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**Subject / Subjekt:** Engine Serial Number 6R0038671

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**Reply / Rückantwort:** Dear Mr. Hanson

Engine serial number 6R0038671 was manufactured in February 1991, as part of engine family MDD12.7FZAX.

The certification levels for the engine family were as follows:

HC 0.1 g/bhp-hr  
CO 2.3 g/bhp-hr  
NOx 4.8 g/bhp-hr  
PM 0.23 g/bhp-hr

Trusting the above to be satisfactory.

Regards  
Joanna Vardas



**TABLE 6. 1991 HEAVY DUTY DIESEL EPA EMISSION STANDARDS**

### Model Year 1987-2003

Model year 1988-2003 US federal (EPA) and 1987-2003 California (ARB) emission standards for heavy-duty diesel truck and bus engines are summarized in the following tables. Applicable to the 1994 and following year standards, sulfur content in the certification fuel has been reduced to 500 ppm wt.

**Table 1**  
EPA Emission Standards for Heavy-Duty Diesel Engines, g/bhp-hr

Year	HC	CO	NO <sub>x</sub>	PM
<b>Heavy-Duty Diesel Truck Engines</b>				
1988	1.3	15.5	10.7	0.60
1990	1.3	15.5	6.0	0.60
1991	1.3	15.5	5.0	0.25
1994	1.3	15.5	5.0	0.10
1998	1.3	15.5	4.0	0.10
<b>Urban Bus Engines</b>				
1991	1.3	15.5	5.0	0.25
1993	1.3	15.5	5.0	0.10
1994	1.3	15.5	5.0	0.07
1996	1.3	15.5	5.0	0.05*
1998	1.3	15.5	4.0	0.05*
* - in-use PM standard 0.07				



**WHITESANDS**  
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**TABLE 7. SwRI MEASURED EMISSIONS ON WHITE SANDS TEST ENGINE**

ETV Base (#EM-5504-F) is our TxLED reference fuel.

Results are for TCEQ engine approval, meeting the 110% emission criteria.

	Run Date	Run #	PM (g/bhphr)	NOx (g/bhphr)	BSFC (g/bhphr)	HC (g/bhphr)	C0 (g/bhphr)	C0 <sub>2</sub> (g/bhphr)
1991 EPA Standards at that time			0.250	5.00	-	1.30	15.50	
1991 Certification Engine emissions			0.230	4.80	-	0.100	2.30	
<b>110% Cert Engine Emissions (=target)</b>			<b>0.253</b>	<b>5.28</b>	-	<b>0.11</b>	<b>2.53</b>	
ETV Base (#EM-5504-F)	Sept 13, 05	1	0.216	4.792	0.384	0.092	2.700	544.8
		2	0.214	4.891	0.384	0.091	2.718	544.6
		Av	<b>0.215</b>	<b>4.842</b>	<b>0.384</b>	<b>0.092</b>	<b>2.709</b>	<b>544.7</b>