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**New Technology Research & Development Program
Grant Contract 582-5-70807-0017**

**Task 3 Deliverable Report
Final Report**

The preparation of this report is based on work funded in part
by the State of Texas through a Grant from the
Texas Commission on Environmental Quality.

NTRD 2005-1; Contract No. 582-70807-0017 Task # 3

Ms. Kate Williams
TCEQ Grant Manager
TCEQ MC-204, Building F
12100 Park 35 Circle
Austin, TX 78753

January 10, 2007

Subject: Task #3 Final EPA Certification

Dear Kate:

Per the contract, I am attaching the requested report for task #3 (645E3B Engine) contract No. 582-5-70807-0017.

Sincerely Yours,

Mark Davis
Systems Engineer
Diesel Engine
GE Infrastructure Rail

**The Preparation of this report is based on work
funded in part by the state of Texas through a
Grant from the Texas Commission on
Environmental Quality**

Tier II NOx 16-645E3B Engine Test Results

Final FTP Results

Final Configuration

Test Date = 02-DEC-2006

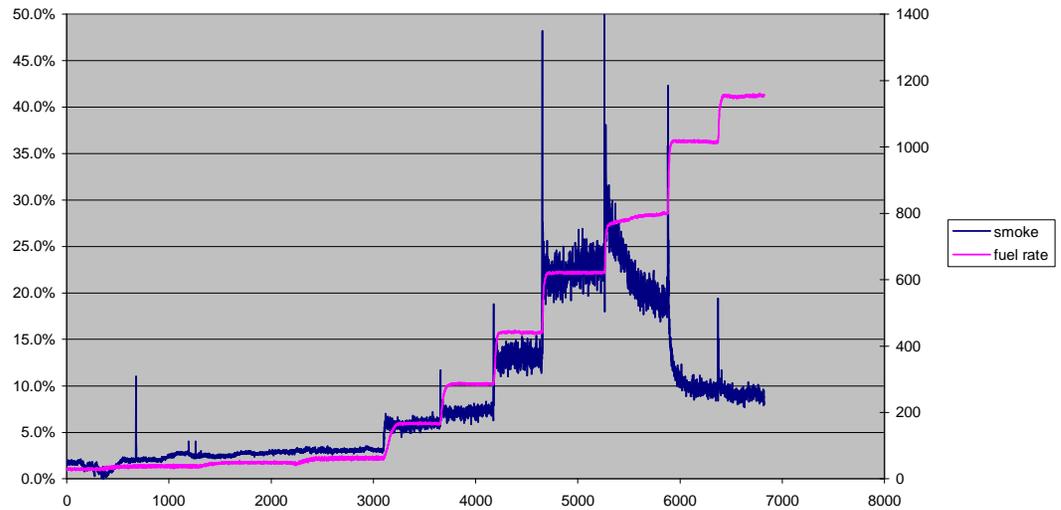
SwRI Project No. 03.05249.04.012

R573.prn

Max ss	Max 30-sec	Max 3-sec
23%	30%	36%
at N5		

Note: Turbo came off the gear @ N6

Final Configuration Smoke Results



EPA Freight Duty Cycle Weighted Results

Notch	WF	w-BHP	w-Fuel		w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-PM w-(g/hr)
			obs w-(lb/hr)	corr. w-(lb/hr)				
LI	19.0%	1.3	5.2	5.2	50.1	28.2	128.0	3.3
Idle	19.0%	1.8	6.8	6.8	60.6	41.5	151.6	3.6
DB2	12.5%	1.8	5.9	5.9	46.4	36.8	114.9	3.4
1	6.5%	6.0	3.9	3.9	18.8	14.7	86.8	1.7
2	6.5%	26.1	10.7	10.6	27.4	20.5	168.8	7.8
3	5.2%	37.6	14.7	14.7	31.3	21.9	218.2	14.5
4	4.4%	50.4	19.3	19.2	32.4	29.7	271.0	23.0
5	3.8%	61.1	23.5	23.4	38.6	77.6	297.2	33.0
6	3.9%	81.2	30.8	30.7	38.6	113.4	378.5	41.5
7	3.0%	82.0	30.4	30.4	35.7	58.1	403.2	28.0
8	16.2%	498.0	186.0	186.1	202.8	326.2	2365.8	153.6
sum =	100.0%	847.4	337.1	336.9	582.5	768.6	4584.0	313.4
			0.398	0.398	0.69	0.91	5.41	0.370
			obs bsfc	corr bsfc	(g/hp-hr)	(g/hp-hr)	(g/hp-hr)	(g/hp-hr)

Reasons for not applying for an EPA Certification:

- Testing has shown that GE Transportation's Tier 2 NOx 645E3B engine meets the EPA Tier 2 NOx limits for both the Line-Haul and Switch duty cycles, and the EPA Tier 0 limits for the balance of the federally-regulated emissions parameters – HC, CO, PM, and smoke (both steady state and transient) – when tested at approximately 700 feet above sea level.
- However, 40CFR Part 92.7(d) requires that “All new locomotives and new locomotive engines ... comply with the applicable emission standards when operated at any altitude less than 7000 feet above sea level.”
- Additionally, the preamble to 40CFR Part 92 states, “While EPA is only requiring that locomotives comply with emission standards when tested at altitudes up to 4000 feet for purposes of certification and in-use liability, it is requiring that manufacturers and remanufacturers submit evidence with their certification applications, in the form of engineering analysis, that shows their locomotives are designed to comply with emission standards at altitudes up to 7000 feet.”
- The analysis conducted by GE Transportation shows that the Tier 2 NOx 645E3B engine is:
 - **unable** to meet EPA Tier 0 steady-state and transient smoke standards over a portion of the full altitude range defined in 40CFR Part 92.
 - **able** to meet the applicable standards for all other federally-regulated emissions parameters over the full altitude range defined in 40CFR Part 92
- The EPA also requires that manufacturers and remanufacturers develop Deterioration Factors (DF's) that take into account potential worsening of emissions over the defined useful life of the locomotive (40CFR 92.9(b)(2)). To account for engine deterioration, the sum of the measured result (on a new or fresh engine) + DF is required to be less than or equal to the EPA limits applicable to each regulated parameter.

Reasons for not applying for an EPA Certification (continued):

- The table below summarizes the results from the final test of the Tier 2 NOx 645E3B engine at Southwest Research Institute. The combined effect of potential deterioration and altitude are also shown:

		Measured Result	Sum of Deterioration and Altitude Factors	Adjusted Result (Measured plus DF/Alt Factor)	Standard
Smoke (% opacity)	ss	23	11.00	34.00	30
	30-sec	30	14.00	44.00	40
	3-sec	36	17.00	53.00	50
Line Haul (g/bhp-hr)	HC	0.69	0.23	0.92	1.00
	CO	0.9	1.34	2.2	5.0
	NOx	5.4	0.00	5.4	5.5
	PM	0.37	0.13	0.50	0.60
Switch (g/bhp-hr)	HC	1.44	0.23	1.67	2.10
	CO	1.4	1.34	2.7	8.0
	NOx	7.3	0.00	7.3	8.1
	PM	0.45	0.13	0.58	0.72

- Although it can be seen that the sum of the measured results and the combined Deterioration and Altitude Factors meet the limits applicable to HC, CO, PM and NOx, the limits are NOT met for smoke (either steady state or transient). Therefore, GE Transportation is unable to submit an application to EPA for a certificate of conformity covering this engine family.

Recommendations for Continued Development, Not in Scope of Work:

1. Electronic Governor – Modify engine speed at certain notch settings to reduce smoke.
2. Increase cooling capacity to reduce MAT. (Separate After Cooling)
3. Install an Oxidation Catalyst Aftertreatment System and burn Low Sulfur Diesel Fuel. (<500ppm)
4. Convert fuel system from Mechanical Unit Injection to Electronic Fuel Injection.

NTRD 2005-1; Contract No. 582-70807-0017

Ms. Kate Williams
TCEQ Grant Manager
TCEQ MC-204, Building F
12100 Park 35 Circle
Austin, TX 78753

March 10, 2007

Subject: Task #3 Final EPA Certification

Dear Kate:

Per the contract, I am attaching the requested report for task #3 (710GG3A Engine) contract No. 582-5-70807-0017.

Sincerely Yours,

Mark Davis
Systems Engineer
Diesel Engine
GE Infrastructure Rail

**The Preparation of this report is based on work
funded in part by the state of Texas through a
Grant from the Texas Commission on
Environmental Quality**

Tier II NOx 16-710G3A Engine Test Results

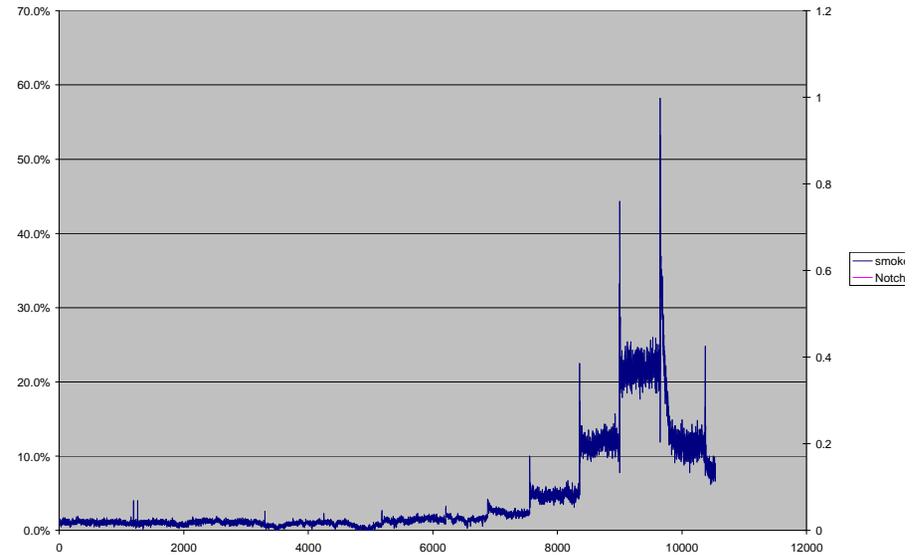
Final FTP Results

GECX5996 Configuration #11

**GECX5996
Configuration #11**

Test date = 26-FEB-2007
SwRI Project No. 03.05249.04.012
R289.prn

Max ss	Max 30-sec	Max 3-sec
22%	40%	60%
at N6		



EPA Freight Duty Cycle Weighted Results

Notch	WF	w-BHP	w-Fuel		w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-PM w-(g/hr)
			obs w-(lb/hr)	corr. w-(lb/hr)				
LI	19.0%	0.9	4.8	4.8	20.5	13.4	143.2	3.0
Idle	19.0%	1.1	6.7	6.7	24.7	20.2	184.1	4.0
DB2	12.5%	1.0	5.9	5.9	19.8	18.6	151.5	3.5
1	6.5%	12.5	6.0	6.0	8.7	6.8	145.2	2.9
2	6.5%	27.6	11.1	11.2	12.4	7.5	275.9	6.0
3	5.2%	50.4	19.4	19.5	18.2	12.7	424.6	15.7
4	4.4%	59.1	22.8	22.8	19.4	27.9	431.6	15.2
5	3.8%	64.3	25.3	25.4	18.9	88.0	392.8	21.0
6	3.9%	83.1	33.3	33.3	20.5	193.9	425.2	37.0
7	3.0%	105.9	40.4	40.4	29.7	152.6	549.6	32.9
8	16.2%	637.8	250.1	250.5	171.3	603.8	3052.4	150.0
sum =	100.0%	1043.7	425.8	426.6	364.1	1145.4	6176.1	291.1
			0.408	0.409	0.35	1.10	5.92	0.279
			obs bsfc	corr bsfc	(g/hp-hr)	(g/hp-hr)	(g/hp-hr)	(g/hp-hr)

Reasons for not applying for an EPA Certification:

- Testing has shown that GE Transportation's Tier 2 NOx 710G3A engine does not meet the EPA Tier 2 NOx limits for either the Line-Haul or Switch duty cycles. Additionally, this engine does not meet the EPA Tier 0 limits for transient smoke (both 30-second and 3-second). This engine meets the EPA Tier 0 limits for the balance of the federally-regulated emissions parameters – HC, CO, PM, and steady state smoke – when tested at approximately 700 feet above sea level.
- However, 40CFR Part 92.7(d) requires that “All new locomotives and new locomotive engines ... comply with the applicable emission standards when operated at any altitude less than 7000 feet above sea level.”
- Additionally, the preamble to 40CFR Part 92 states, “While EPA is only requiring that locomotives comply with emission standards when tested at altitudes up to 4000 feet for purposes of certification and in-use liability, it is requiring that manufacturers and remanufacturers submit evidence with their certification applications, in the form of engineering analysis, that shows their locomotives are designed to comply with emission standards at altitudes up to 7000 feet.”
- The analysis conducted by GE Transportation shows that the Tier 2 NOx 710G3A engine is:
 - **unable** to meet EPA Tier 2 Line Haul and Switch Duty Cycle NOx standards over the full altitude range defined in 40CFR Part 92.
 - **unable** to meet EPA Tier 0 transient smoke standards (3-second and 3-second) over the full altitude range defined in 40CFR Part 92.
 - **unable** to meet EPA Tier 0 steady state smoke standards over a portion of the full altitude range defined in 40CFR Part 92.
 - **able** to meet the applicable standards for all other federally-regulated emissions parameters over the full altitude range defined in 40CFR Part 92.

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Reasons for not applying for an EPA Certification (continued):

- The EPA also requires that manufacturers and remanufacturers develop Deterioration Factors (DF's) that take into account potential worsening of emissions over the defined useful life of the locomotive (40CFR 92.9(b)(2)). To account for engine deterioration, the sum of the measured result (on a new or fresh engine) + DF is required to be less than or equal to the EPA limits applicable to each regulated parameter.
- The table below summarizes the results from the "Configuration 11" test of the Tier 2 NOx 710G3A engine at Southwest Research Institute. The combined effect of potential deterioration and altitude are also shown:

		Measured Result	Sum of Deterioration and Altitude Factors	Adjusted Result (Measured plus DF/Alt Factor)	Standard
Smoke (% opacity)	ss	22	11.00	33.00	30
	30-sec	40	11.00	51.00	40
	3-sec	60	11.00	71.00	50
Line Haul (g/bhp-hr)	HC	0.35	0.23	0.58	1.00
	CO	1.1	1.34	2.4	5.0
	NOx	5.9	0.48	6.4	5.5
	PM	0.28	0.13	0.41	0.60
Switch (g/bhp-hr)	HC	0.58	0.23	0.81	2.10
	CO	1.0	1.34	2.3	8.0
	NOx	9.1	0.48	9.6	8.1
	PM	0.32	0.13	0.45	0.72

- Although it can be seen that the sum of the measured results and the combined Deterioration and Altitude Factors meet the limits applicable to HC, CO, and PM, the limits are NOT met for NOx (either LH or Switch) and smoke (either steady state or transient). Therefore, GE Transportation is unable to submit an application to EPA for a certificate of conformity covering this engine family.

Recommendations for Continued Development, Not in Scope of Work:

1. Electronic Governor – Modify engine speed at certain notch settings to reduce smoke.
2. Increase cooling capacity to reduce MAT. (Separate After Cooling)
3. Install an Oxidation Catalyst Aftertreatment System and burn Low Sulfur Diesel Fuel. (<500ppm)
4. Convert fuel system from Mechanical Unit Injection to Electronic Fuel Injection.