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Technical Report

Testing of the Mack ETSA-676 at MVEL

by

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NOTICE

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Table of Contents

I. Summary

The Mack ETSA-676 heavy-duty diesel engine has been tested at EPA as part of the EMA/EPA testing program. The purpose of this program is to analyze lab-to-lab variability in emissions measurements and to assess how well the emissions data generated at EPA correlates with data acquired through testing at other laboratories. This engine was scheduled to be tested in turn by Mack Trucks, Inc. (Mack), Caterpillar Tractor Co. (Cat), and EPA, and then to be returned to Mack for the final tests on this engine as part of the program.

EPA's correlation with other labs has been generally acceptable with a tendency to somewhat higher particulate measurements in comparison with those of other labs. This was reviewed in detail in other reports[1,2] and will not be dealt with further here.

EPA's transient test particulate measurements for this engine were 7.8 percent higher than Mack's and 31.12 percent higher than Cat's: .77, .71, and .53 g/BHP-hr, respectively. The transient values for NOx were 25.2 percent higher than Mack's and 19.3 percent higher than Cat's: 8.45, 6.32, and 6.82 g/BHP-hr, respectively. The HC emissions measurements at EPA were 49.1 percent lower than Mack's and 28.1 percent lower than Cat's: .57, .85, and .73 g/BHP-hr, respectively.

Steady-state emission values did not follow the same pattern as the above listed transient test data. EPA's 13-mode particulate measurements were 53.5 percent higher than Mack's and 20.9 percent lower than Cat's: .86, .40, and .68 g/BHP-hr, respectively. NOx measurements were 8.5 percent higher than Mack's and 19.2 percent lower than Cat's: 6.83, 6.25, and 8.14 g/BHP-hr, respectively. HC emissions were 20.8 percent lower than Mack's and 8.3 percent lower than Cat's: .48, .58, and .52 g/BHP-hr, respectively.

Mode 6 and Mode 11 particulate emission measurements were not reported by Mack and the only comparison made is between Cat and EPA. Cat particulate measurements were 22.4 percent lower than EPA's in Mode 6 and 58.0 percent higher than EPA's in Mode 11.

The engine has been returned to Mack for the final test in the schedule and in view of the somewhat inconsistent data generated by this engine at the labs involved, a final evaluation of correlation should be delayed pending review of the data forthcoming from Mack's second test series.

II. Introduction

This report is one of a series of reports presenting results, analysis and conclusions of testing heavy-duty diesel engines at

the EPA's Motor Vehicle Emission Lab (MVEL). These engines are tested in both transient and steady-state modes and the resulting data is compared with that of other test labs to determine the amount of variability between labs.

This report discusses the results of testing a Mack heavy-duty diesel engine, model ETSA-676. Reviewed are some problems encountered during the course of testing the engine and the procedures followed to isolate and solve the problems satisfactorily. Finally, recommendations for improved procedures will be presented.

III. Test Results and Correlation With Other Test Laboratories

A series of transient tests were run on this engine from November 16, to December 1, 1981, at which time the particulate measurements inexplicably rose from a range of .553 to .837 grams per BHP-hr to values of 1.046+ grams per BHP-hr. The testing was stopped while propane checks were initiated to detect leaks and the components in the system were checked. A leaking thermocouple fitting in the mini-tunnel, a cracked sampling line and secondary dilution air inlet temperature variations all contributed to the erratic readings and were corrected.

Testing was resumed with more consistent performance and data were processed and compared with that of other labs. The test results from the three labs involved in testing the Mack ETSA-676 engine are shown in Table 1. Shown are composite emissions for transient tests, and 13-mode steady-state emissions. Table 2 shows the detail of the data summarized in Table 1. Table 3 lists the cycle performance data for the tests, indicating that all tests listed were valid.

Examining the data in Table 1, the values for NOx differ substantially among the three testing labs using EPA's values as a base: Cat:transient -19.3 percent,* 13-mode +19.2 percent; Mack:transient -25.2 percent, 13-mode -8.5 percent.

In contrast, other's measurements of HC emissions are well above those of EPA: Cat:transient +28.1 percent, 13-mode +8.3 percent; Mack:transient +49.1 percent, 13-mode +20.8 percent.

The values for particulates show an even greater dispersion: Cat:transient -31.2 percent, 13-mode -20.9 percent; Mack:transient -7.8 percent, 13-mode -53.5 percent. As was noted earlier in the report, the particulate measurements at EPA are higher than those of other labs.

* $$\% \text{ Difference} = \frac{\bar{x}\ \text{Mfr} - \bar{x}\ \text{EPA}}{\bar{x}\ \text{EPA}} \times 100$$

IV. Analysis of Testing Problems

As a result of experience gained in testing the baseline and other engines, a set of recommended procedures was set up to be observed during subsequent testing of heavy-duty engines. These procedures were followed during the testing of this Mack engine. There were, however, some problems incurred which at times required tests to be voided. As mentioned above, a set of transient tests was invalidated because of a sudden rise in particulate measurement. A series of propane leak tests were performed to identify the cause(s). Among items found and corrected were:

1. Leaking thermocouple fitting on mini-tunnel - sealed.

2. Sample line split at fitting - repaired.

3. Inlet and outlet temperatures running higher than spec. - increased length of sample lines.

4. Outlet from exhaust DGM was within 6" of inlet to DGM - relocated exhaust DGM to vent to air handling system.

5. Scrubbed main tunnel.

6. Inspected all lines and fittings.

7. Verified calibration of all components.

V. Conclusion

Although previous engines tested at EPA had exhibited particulate measurements higher than those measurements at other labs, the inconsistent values obtained from this engine at EPA and Caterpillar preclude any valid conclusion being drawn at this time. The HC and NOx values are also without a predictable pattern.

VI. Recommendations

Any final evaluation of test data produced from previous tests of this engine should be withheld until the second set of tests being conducted by Mack are concluded. The results from these tests should then be reviewed and evaluated against the previous test data produced at all labs involved with this engine. At this time it may be determined if indeed the engine is erratic in performance or our labs have other problems to be isolated and solved.

References

1. "Emissions Testing of a DDA 6V92TA Heavy-Duty Diesel Engine Under Transient Conditions," Danielson, Eugene, EPA-AA-SDSB-80-16, September 1980.

2. Emissions Testing of an IHC DTI-466B Heavy-Duty Diesel Engine Under Transient Conditions," Danielson, Eugene, EPA-AA-SDSB-80-18, September 1980.

Table 1

Summary of Mack ETSA-676 Emissions Tests
(g/BHP-hr)

Test Site	Stat	NOx				HC				Part.			
		Trans.[1]	13-Mode	Mode 6	Mode 11	Trans.[1]	13-Mode	Mode 6	Mode 11	Trans.[1]	13-Mode	Mode 6	Mode 11
Mack	$\bar{x}$	6.32	6.25	5.30	5.70	.85	.58	.062	1.39	.71	.40	-	-
	s	.430	.040	.057	.311	.118	.005	.006	.057	.033	.010	-	-
	$s/\bar{x}$ x 100	6.8%	.6%	1.1%	5.5%	13.8%	.8%	9.7%	4.1%	4.6%	2.5%	-	-
	% Diff.[2]	-25.2	-8.5	-25.8	-11.2	+49.1	+20.8	+520.0	-2.1	-7.8	-53.5		
Cat	$\bar{x}$	6.82	8.14	7.60	6.89	.73	.52	.012	1.42	.53	.68	1.35	.79
	s	.163	.387	.255	.471	.007	.055	.016	.103	.150	.069	.141	.019
	$s/\bar{x}$ x 100	2.4%	4.7%	3.4%	6.8%	1.00%	10.6%	1.3%	7.2%	28.4%	10.1%	10.5%	2.4%
	% Diff.[2]	-19.3	+19.2	+6.4	+7.3	+28.1	+8.3	+20.0	0.0	-31.2	-20.9	-20.9	+58.0
EPA	$\bar{x}$	8.45	6.83	7.14	6.42	.57	.48	.010	1.42	.77	.86	1.74	.50
	s	.265	.997	.634	.382	.064	.020	.0017	.021	.030	.094	.020	-
	$s/\bar{x}$ x 100	3.1%	14.6%	8.9%	6.0%	11.2%	4.2%	7.0%	1.5%	3.9%	10.9%	1.1%	-

[1] Composite C/S-H/S data.

[2] % Difference = $\frac{\bar{x}\ \text{Other} - \bar{x}\ \text{EPA}}{\bar{x}\ \text{EPA}} \times 100$

Table 2

Transient Emissions		Test Site Mack	Cat	EPA
NOx	Cold $\bar{x}$	6.06	7.04	8.80
	Hot $\bar{x}$	6.83	6.68	8.39
	Comp $\bar{x}$	6.32	6.82	8.45
	Hot S	.390	.156	.296
	$s/\bar{x} \times 100$	5.7%	2.3%	3.5%
HC	Cold $\bar{x}$	.99	.80	.64
	Hot $\bar{x}$	.78	.74	.56
	Comp $\bar{x}$	.85	.73	.57
	Hot S	.066	.015	.064
	$s/\bar{x} \times 100$	8.5%	2.0%	11.4%
Part	Cold $\bar{x}$	.70	.66	.83
	Hot $\bar{x}$	.66	.56	.76
	Comp $\bar{x}$	.71	.53	.77
	Hot S	.019	.059	.027
	$s/\bar{x} \times 100$	2.9%	10.5%	3.6%
Filter Efficiency				
	$\bar{x}$	98.0	98.0	98.2
	s	-	0.95	2.19

Table 3

EPA/MVEL Mack ETSA-676 Cycle Performance Data

Type/	Speed				Torque				HP				Integrated
Limit	Error	Slope	y-Intercept	R^2	Error	Slope	y-Intercept	R^2	Error	Slope	y-Intercept	R^2	HP-Hr
	100	.970-1.030	±50 RPM	.97 min	13% of Max Torque	.77/.83 1.03 Cold/Hot	±15#	.85/88 min Cold/Hot	8% of Max HP	.87/.89 -1.03 Cold/Hot	±5.0 BHP	.91 min	-15% to +5% Ref.
C/S	35.2	.980	24.1	.995	6.4	.986	5.48	.942	6.5	1.02	-1.09	.955	1.01
H/S	34.3	.980	26.0	.995	6.4	.978	8.35	.943	6.4	1.02	-.787	.956	1.02
C/S	34.7	.979	18.7	.995	6.6	.987	-2.63	.936	6.7	1.01	-2.26	.950	.981
H/S	34.2	.980	17.6	.996	6.6	.980	-1.01	.936	6.7	1.00	-2.15	.949	.986
C/S	34.7	.973	13.9	.995	6.5	.993	-2.9	.942	6.5	1.00	-2.2	.954	.978
H/S	34.8	.972	12.7	.995	6.3	.990	-1.5	.945	6.4	1.00	-2.1	.955	.986
C/S	34.8	.974	26.4	.995	6.4	.991	-9.81	.942	6.5	1.01	-1.90	.953	.991
H/S	34.5	.974	26.5	.995	6.2	.990	-1.121	.946	6.4	1.01	-1.84	.956	.998
C/S	34.6	.970	1.04	.995	6.4	.991	-2.78	.942	6.4	.991	-2.19	.953	.964
H/S	34.4	.969	1.88	.995	6.4	.983	-0.78	.944	6.4	.987	-2.02	.954	.970