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Technical Report

Evaluation of the Contamination Effects of Diesel Exhaust on a Critical Flow Sample System

by

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NOTICE

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Abstract

Testing has been conducted to determine 1) the effectiveness of complete diluted diesel exhaust stream filtering in preventing contamination of a CFV sample system, and 2) the effect of this filtering on diesel gaseous emission meaurements. Contamination was evaluated by observing the repeatability of gaseous emissions measurements from a gasoline vehicle which was operated between each of several diesel test sequences. Special attention was given to detecting hydrocarbon contamination by 1) measuring the concentration of injected propane (between diesel tests), and 2) by comparing concentrations of hydrocarbons in background air sampled through the CFV (exposed) sample system to the measured concentrations of hydrocarbons in background air sampled through the background (unexposed) sample system. These latter comparisons were also made between diesel tests.

The effect of exhaust stream filtering on the levels of CO, CO_2 and NOx in diesel exhaust was determined by comparing these levels with and without filtering.

The results of this testing indicate that complete filtering of diluted diesel exhaust immediately before the CFV inlet is effective in preventing CFV contamination. Further, filtering of the diesel exhaust before the CFV inlet does not appear to effect the measured levels of CO, CO_2 and NOx in diesel exhaust. (HC is measured before the CFV filter.)

Introduction

EPA's new interim transient heavy-duty diesel site at MVEL (Ann Arbor) will utilize a CFV sample system. Considerable concern has been expressed about the possibility of contaminating this sample system with the heavy hydrocarbon and particulate material contained in diesel exhaust. The only known laboratory where an unproteded CFV is used for diesel testing is the DOT laboratory in Cambridge, Massachusetts. Conversation with personnel at that facility indicate that the main CFV nozzle must be cleaned once every four hours (test time) in order to maintain a valid flow calibration. Such frequent cleaning would dramatically delay test programs at MVEL, and hence, an alternative was sought.

Other laboratories (notably GM labs) filter the complete exhaust stream when testing diesels on a CFV system. This is known as bulk stream filtering, and has the advantage of directly protecting the CFV system from diesel particulate contamination. This means that potential periodic shut downs for nozzle cleanings can be eliminated.

However, data providing information on the effectiveness of the concept were not available. In addition, it was unknown whether or not bulk stream filtering of the diesel exhaust would affect the measured levels of the bagged emissions (CO, CO_2, and NOx). Therefore, a test program aimed at evaluating the effectiveness of bulk stream filtering and its impact on the bagged emissions was conducted using the part scale double-dilution system (i.e., a light-duty vehicle operated on chassis dynamometer and a 350 cfm CFV unit connected to the primary tunnel of a double-dilution system).

Objective

This study was conducted primarily to evaluate the effectiveness of using bulk stream filtering to protect a CFV sample system when testing diesel vehicles. A secondary objective of this study was to obtain an indication of the impact of bulk stream filtering on the bagged diesel exhaust emissions.

Test Procedure

Before an analysis and discussion of the data is presented, a detailed description of the test sequence and equipment is necessary.

Events 1 through 4, listed in Table 1, indicate the general test sequence and corresponding CFV configuration used to evaluate contamination (primary objective). The basic philosophy used in this program was to expose the CFV to diesel exhaust (Event 1), and then measure the effect on gasoline vehicle emissions (Event 2). In addition, propane and background hydrocarbon samples were taken to provide additional check on hydrocarbon contamination in the CFV. After establishing a baseline of gasoline vehicle emissions and propane levels, and taking initial background measurements, it was intended to repeat the sequence five times without interruption.

However, at the end of the second sequence, it was apparent that the CO and HC emissions from the gasoline vehicle (a 1976 Chevette) were not repeating. It was suspected that this was being caused by a malfunction in the "hot stove" valve that controls the flow of heated manifold air entering the carburetor. However, possible contamination could not be ruled out. Some confirmatory testing was necessary. This confirmatory testing consisted of measuring the emissions from another vehicle (a 1977 Chevette) using an unexposed (to diesel exhaust) CFV and then subsequently measuring its emissions using the exposed CFV. With this vehicle, there were essentially no differences in the levels of measured emissions between the two CFVs. It was concluded from this, that the CO and HC nonrepeatability was vehicle related. Therefore, the 1977 Chevette was used to finish the testing.

This final series of tests with the '77 Chevette provided data which were used to evaluate diesel contamination of the CFV. This was the primary objective of the study. A secondary objective was to quantify the effect of bulk stream filtering on the bagged diesel emissions (CO, CO_2, and NOx). This evaluation consisted of comparing filtered diesel exhaust emission levels to unfiltered diesel exhaust emission levels. The filtered exhaust data came from measurements taken during Event 1. The unfiltered exhaust data came from measuring the bagged emissions during a series of tests in which no bulk stream filter was used. These nonfiltered exhaust measurements were taken using a conventional PDP-CVS because it was expected that unfiltered diesel exhaust would very likely contaminate a CFV system.

Results

Contamination Evaluation

The emission levels of the two Chevettes plus the propane injection and background levels are presented in Figures 1, 2, and 3. All of the gasoline vehicle emission levels were measured over the hot LA-4 cycle.

Any contamination of the CFV by diesel exhaust was expected to primarily affect HC measurements. In this regard, the HC data presented in Figure 1 is of primary interest. This data indicates that there is no HC contamination of the CFV system as measured by any of the comparisons available. The measured HC levels of both Chevettes remained unchanged (except for the second sequences of the 1976 Chevette discussed in the test procedure section) throughout the complete sequence of events. Similarly, the measured HC level during propane injections also remained constant. Finally, the background HC levels sampled through the CFV sample line are essentially equal to the background HC levels sampled through the background line. This is significant because the sample lines were exposed to the diesel exhaust while the background lines were not exposed to diesel exhaust. From these comparisons, it was concluded that there were no residual diesel hydrocarbons contaminating the CFV sample system.

Exposing the CFV sample system to filtered diesel exhaust was not expected to have any appreciable effect on the CO, NOx, and CO_2 gasoline vehicle measurements. The data presented in Figures 2 and 3 confirm that these measurements were in fact unaffected. That is, there were no steady trends (either increasing or decreasing) in these measurements. If there had been deterioration a definite trend should have appeared for the number of tests that were conducted.

Effect of Bulk Stream Filtering on Diesel Emissions (CO, NOx, and CO_2)

The question has been raised as to whether or not bulk stream filtering affects the measurements of CO, NOx, and CO_2 in the diesel exhaust. To help address this question, measurements of the CO, CO_2 and NOx levels in the filtered exhaust were taken during the diesel events (Table 1). Immediately after the contamination evaluation testing was completed, unfiltered exhaust gaseous emission measurements were made using a conventional PDP-CVS. Table 2 presents a comparison of the filtered exhaust to unfiltered exhaust levels of CO, CO_2 and NOx. From this comparison, it appears that there is no appreciable change in the measured bagged emissions levels.

It should be noted that hydrocarbon and particulate measurements were also taken during both the CFV and PDP-CVS diesel testing. These measurements were taken in order to quantify the respective errors due to non-proportional sampling (i.e., using the CFV without a heat exchanger). The analysis and results of this testing are presented in a yet to be published Technical Report entitled "Hydro-carbon and Particulate Sample Errors Due to Non-Proportional Sampling".

Discussion and Conclusion

The results stated previously indicate that there was no apparent contamination of the CFV sample system from diesel exhaust. Contamination of the CFV sample system would have been expected to be cumulative. However, none of the Chevette tests, nor any of the propane and background measurements indicated any contamination. The bulk stream filtering seems to have sufficiently deterred contamination. In addition, the bulk stream filtering of the exhaust did not appear to have any appreciable effect on the measurements of diesel CO, CO_2 and NOx. Therefore it was concluded from this testing that bulk stream filtering is one viable method of protectng a CFV sample unit from diesel exhaust contamination.

Recommendation

It is recommended that bulk stream filtering be allowed for use in protecting CFV sample systems from diesel contamination.

Table 1

CFV Diesel Contamination Testing
Sequence of Events

Event	Sample Type	CFV Configuration
1	Diesel Vehicle Testing (4-Bag FTP + 2 Hot LA-4s)	CFV connected to 18-inch tunnel per FR Vol.44, No.23, Feb. 1, 1979 Figure B81-4 except: 1) no heat exchanger and 2) a bulk stream filter was installed between the dilution tunnel and the CFV.
2	Gasoline Vehicle Testing (2 LA-4s) 1/	Standard light-duty set-up per FR Vol. 42, No. 124, June 28, 1977, Figure B78-2.
3	Propane Injection (Replicate samples)	
4	Background HC Check; Replicate samples taken with main CFV sample system and with background sample system.	

1/ For the initial baseline testing, 3 LA-4s were driven.

Table 2

Gaseous Emissions Test Comparison

Peugeot 504D
Hot LA-4 Driving Cycle

Measurement System	CO (gm/mi)	CO2 (gm/mi)	NOx (gm/mi)
Unfiltered Exhaust - PDP CVS connected to 18-inch dilution tunnel per FR Vol. 44, No. 23, Feb. 1, 1979, Figure B81-3.	1.36 ± 3.7%	361 ± 2.7%	1.26 ± 2.0%
Filtered Exhaust - CFV connected to 18-Inch dilution tunnel per FR Vol. 44, No. 23, Feb. 1, 1979, Fig. B81-4 Except: 1) No heat exchanger, and 2) A bulk stream filter was installed between dilution tunnel and CFV.	1.42 ± 1.1%	367 ± 1.6%	1.26 ± 3.6%
Difference	+ 4.4%	+ 1.7%	0

NOTE:

1) The bulk stream filter was changed after each diesel test sequence;

2) The pressure drop across the filter was monitored during all CFV diesel testing to be sure that the upstream CFV pressure did not change too much. (A large change in this pressure would effect the CFV flow rate). The maximum pressure drop observed was only 1 inch H_2O. This small pressure change would have a negligible effect on the CFV flow.

SYMBOLS -- ABBREVIATIONS

- Denotes tests with CFV sample unit exposed to diesel exhaust.

- Denotes tests with CFV sample unit not exposed to diesel exhaust.

DTS - Denotes Diesel Test Sequence

FIGURE 1

CFV-CVS GAS CAR CONTROL RUNS

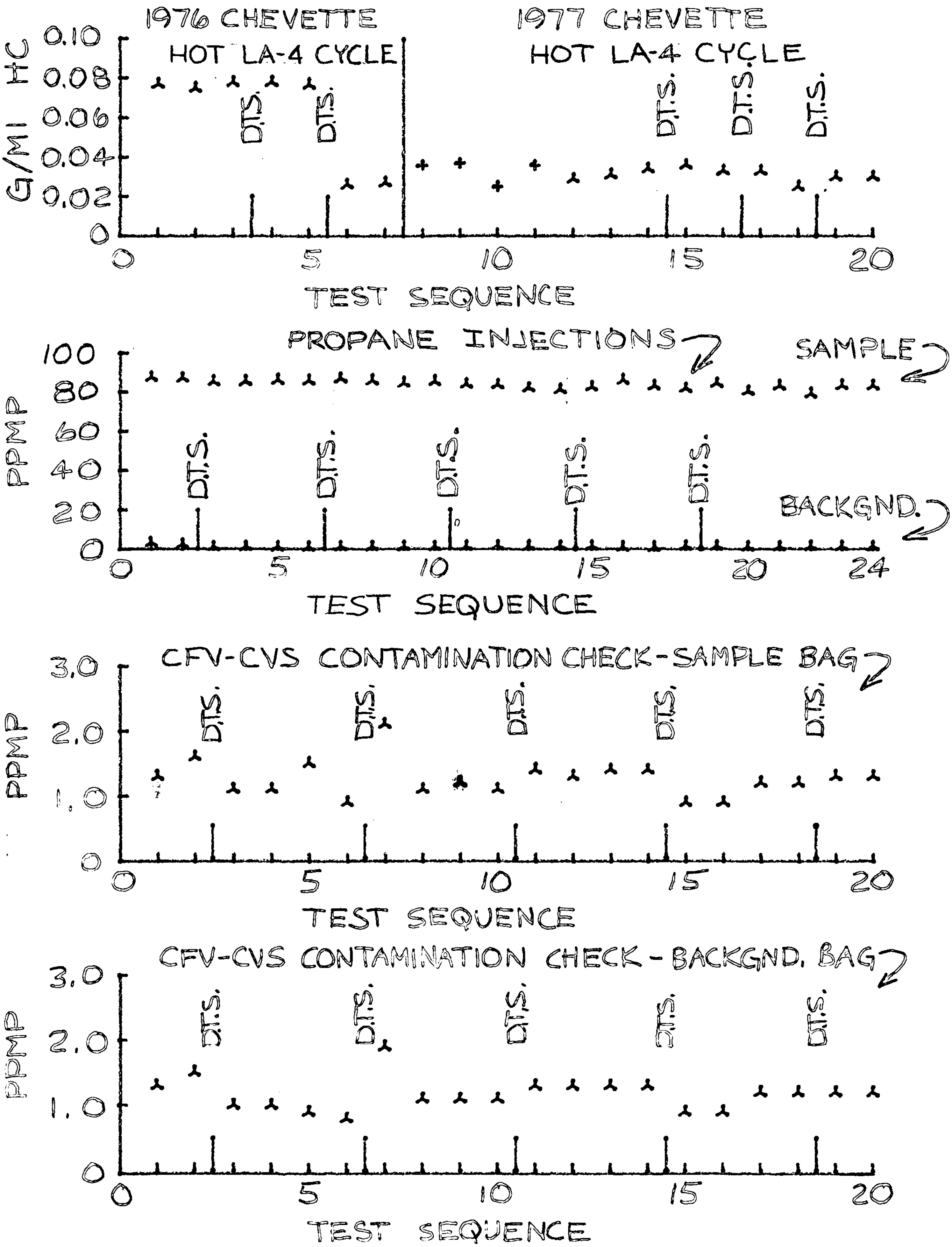
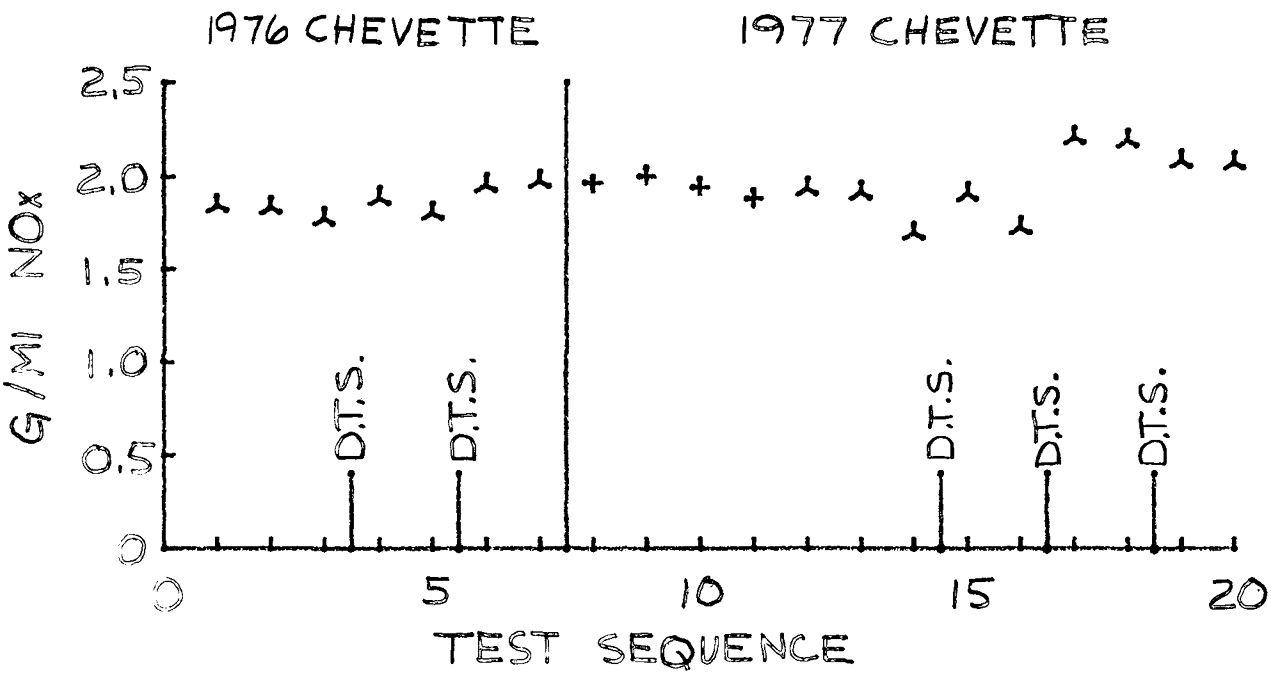


FIGURE 2
(ALL TESTS HOT LA-4 CYCLE)



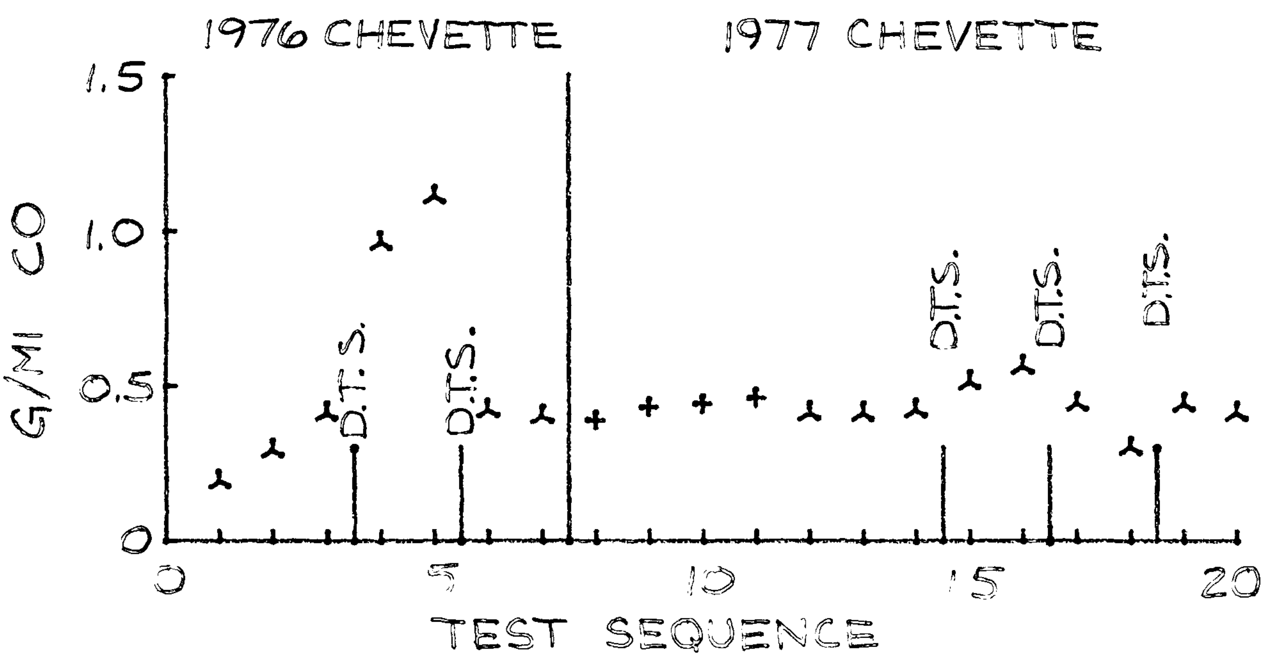


FIGURE 3
(ALL TESTS HOT LA-4 CYCLE)