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Background:

EPA requirements for “high enhanced I/M testing” include conducting pressure and purge tests for identifying vehicles with excess evaporative emissions, and these requirements are published in the Code of Federal Regulations Part 51. Since the start of IM240 exhaust and evaporative emission testing, conducting the purge test has been problematic for several reasons. The original problems included the time constraints to run the EPA flow meter method in high volume I/M test lanes, and the intrusive nature of the purge test which sometimes resulted in breaking evaporative emission components while installing the purge flow meter described in EPA IM240 and Evap Technical Guidance. These problems are related to the design and location of vehicles’ evaporative emission control systems, and the fact that they were never designed to be evaluated with an IM240 test.

The purpose of the I/M purge test is not to provide an accurate quantitative mass measurement of total evaporative emission hydrocarbon, but rather provide an accurate qualitative indication of whether a vehicle has a malfunctioning purge system. Although EPA was able to develop a qualitative purge test using a flowmeter installed between the canister and the engine intake, this method did not translate well from the laboratory environment to actual I/M test lanes.

EPA has previously evaluated alternative purge test equipment and procedures such as the helium tracer method, and discussed alternative concepts with auto manufacturers and research and testing organizations.

This evaluation compared the ability of two I/M prototype instruments to correctly determine whether the purge systems on 1981-1995 model year vehicles are functional. The instruments were provided by Sensors Inc. and by Leo Breton and Dennis Johnson of EPA’s Engine Programs and Compliance Division of the Office of Mobile Sources.

Objective:

The purpose of this evaluation was to examine the prototypes and determine if it is desirable to commit further development effort on these methods in pursuit of an I/M purge test for pre-OBD II vehicles. This report presents the results of the evaluation of the two prototypes at Automotive Testing Laboratories (ATL) in January, 1999.

An acceptable purge test requires that the instrument and test procedures meet design specific challenges which are both vehicle and I/M test specific.

These challenges include the following vehicle specific issues:

1) The method must be applicable to the variety of evaporative emission designs used in light duty vehicles and trucks from the 1981-1995 model years. Purge flow is controlled by solenoids and electronic control modules (ECMs), thermal switches, engine vacuum, and sometimes vehicle speed sensors. Purge flow may be constant when some of the criteria above are satisfied, or modulated, cycling between zero and maximum flow when commanded to do so. Flow rates vary greatly, typically between 10-200 cc/sec of air and hydrocarbon mixture.

2) The canister purge lines vary greatly in their accessibility and length of line. In approximately 30% of the in-use fleet, the canister is not visible from the engine compartment, is sometimes sealed in body components, or is visible only from underneath the vehicle.

3) The purge lines vary from less than a 1/4 inch outside diameter (OD) to about ½ inch OD, and vary in material composition from hard plastic and age/temperature hardened polymer lines to soft lines. Age hardened lines are often fragile and will break when they are removed.

4) The lines are frequently located close to hot engine surfaces making access to them a safety issue. Electrical noise and engine vibration are usually present in the engine compartment which can interfere with electrical equipment and vibration sensitive sensors, respectively.

Purge test criteria specific to I/M purge testing include the following test specific issues:

1) The qualitative identification of purge system failures should be accurate, with a goal of no more than a 5% false fail rate, and a 10% false pass rate. These 5 and 10% rates are not based on established EPA guidelines, but rather are thought to provide a reasonable engineering objective that would be acceptable to I/M stakeholders, and provided a common design objective for the suppliers of the two prototype purge devices.

2) For each model year, the method should be able to be run on at least 70% of the 1981-1995 model year vehicles. 1996 and later vehicles will be able to use OBD II scan tools to identify purge system failures. The 70% criteria is based on EPA judgement as to what might be acceptable to I/M stakeholders.

3) Preferably, the instrument should be able to be installed without shutting off the engine, as turning the engine off will result in delaying the start of purge flow in some vehicles for 2-4 minutes.

4) It is desirable that the purge flow measurement be conducted simultaneously with conducting the I/M exhaust test as this will not add to the total test time. If the method is run simultaneously with the I/M exhaust test it must not influence the exhaust emission results. The purge flow test is not always compatible with an idle or steady state test. If the method must be run as a stand-alone test using a transient driving cycle, the test length should be no longer than 60 seconds.

5) The method should be non-intrusive. Removing or cutting purge lines and installing a flow meter is an intrusive method. The method should not leave visual evidence that a purge test has been run.

6) The instrument should be operational under ambient conditions varying from 0-40 °C and engine compartment temperatures of about 10-70 °C.

7) The instrument must be capable of use in an extremely rugged operational environment.

8) The instrument must include a means of verifying its functionality on a daily or weekly basis.

This set of criteria, excepting items 6-8, which were not part of this evaluation, served as the basis for deciding if the purge test prototypes warranted further development effort.

Instrument Descriptions

The description of the operating techniques behind the two prototypes is limited for two reasons. 1) The design concepts for the two instruments are proprietary, and patents are being explored for parts of one or both designs. 2) The designs evaluated were prototypes, and therefore some of the limitations and problem areas observed in this test program could be resolved by redesign and building second generation prototypes.

EPA - The EPA computer controlled prototype is based on a strain gage (load cell) design where purge flow is sensed by comparing the purge line diameter in a no-flow state and then in a condition when purge flow is present. The EPA method uses two pieces of hardware placed over the purge line to make its assessment, a pneumatically actuated clamping device, which alternately produces a flow and no-flow condition, and the sensing element which is a strain gage load cell which measures the difference in the contraction of the purge line between a flow and no-flow condition. The no-flow condition is achieved by momentarily clamping the purge line using a pneumatically actuated piston. When the supply pressure to the piston is released, the purge line returns to its unclamped state and the load cell measures the contraction in the purge line.

This measurement method is a qualitative technique, and depends on the ability to sense purge flow a selected number of times (a minimum of eight in this evaluation) during a maximum test period of four minutes. The EPA prototype is computer controlled and calibrated, and shows the purge or no-purge condition by displaying the number of times purge flow is sensed. Eight determinations of purge flow in a period of four minutes or less produce a “pass” status on the computer monitor.

A more complete description of the EPA method is presented in Appendix 2. Appendix 3 is a figure provided by ATL and shows the positioning of the load cell sensor and the clamping device used for the 85 vehicles examined with the EPA tester.

Sensors - The Sensors prototype is based on an application of flow measurement used in medical science. The basic principle is flow measurement using an approximate 0.040 in. diameter needle probe and an application of hot wire anemometry to measure flow rate. A computer initiates the test and displays instantaneous and cumulative purge flow over time. When the cumulative flow equals one liter the computer displays a “pass” condition. If less than one liter of flow is measured by the end of the four minute driving cycle, a fail determination is made.

The method requires care to position the needle in the approximate center of the purge line cross sectional area, which for this program, was done manually by the test technician. Sensors has provided EPA with sketches of a “packaging concept” which would always ensure the needle was properly located in the flow stream.

At the time of this evaluation, the only documentation available was a brief operating procedure supplied by Sensors and engineering concept drawings of a proposed centering and packing design. The operating procedure is included as Appendix 4.

Test Fleet

100 1981-1995 vehicles were recruited from the Mesa, AZ I/M emission test station during the period January 7-28, 1999. The 100 vehicle sample included a variety of model years and an approximate 50% split of light duty vehicles and light duty trucks. No attempt was made to obtain a sample representative of the AZ in-use fleet because the program design was simply an evaluation of the prototype devices and did not attempt to make inferences about the in-use test fleet. A $25 cash incentive was paid to obtain each test vehicle for a period of about 30 minutes.

Test Protocol

All tests were conducted between January 7 and January 28, 1999 in the inspection bay of the ATL Mesa, AZ emission test facility. In its most simplistic design, the protocol called for installing each prototype in series with a reference method and observing the response. This was done both for vehicles in an as-received condition, and after an induced failure of the purge system.

The test protocol consisted of the following steps:

1) Record vehicle and purge system descriptive data from each vehicle.

2) Connect a 0-10 standard cubic feet per hour (SCFH) roto-meter with a shutoff valve to induce a “failed” mode in the canister purge system. Install a slave purge line if necessary.

3) Alternate the installation of either prototype method.

4) Exercise the vehicle at combinations of steady state operation and/or rapid accelerator variation to induce and verify purge flow using the roto-meter. Take the appropriate time to ensure that vehicles with operating purge systems satisfy any engine temperature, drive time criteria, throttle actuation requirements, and, in some cases, wheel speed operation by placing the vehicle on a hoist in the ATL inspection bay and placing the transmission in drive.

5) Compare the roto-meter and prototype device qualitative determinations of purge flow.

6) Turn the shut-off valve on the roto-meter to induce a “purge failure.”

7) Repeat steps 4 and 5 with the first prototype instrument.

8) Install the second prototype and repeat steps 4 and 5.

9) Turn the shut-off valve on the roto-meter to induce a “purge failure.”

10) Repeat steps 4 and 5 with the second prototype.

Years of ATL testing experience has established that observing purge flow on the IM240 driving cycle with a roto-meter will, with near certainty, produce the same qualitative result as an in-line flow meter. In this study, success with either prototype device was defined as qualitative agreement with the roto-meter method, i.e. can they determine when the purge system has some flow, or none. Neither prototype was designed to produce accurate quantitative correlation with a known reference method such as a totalizing flow meter.

If the prototype device could not sense flow when flow was observed with the roto-meter, the prototype was not tested in the induced failure mode. The rationale for this was that the prototype would again have indicated no-flow, but only because it was not performing correctly for that particular vehicle.

Test time with each method was recorded for vehicles 33-100. Average test times for the prototypes are calculated for the as-received tests, and do not include time to locate the purge line or exercise the vehicle to obtain a purge condition as proven by the roto-meter. For the induced failure mode, the test was run for four minutes, thus simulating what might be done in an IM240 test if the purge device did not show a fast pass during the IM240 exhaust test.

Results

The evaluation program did not attempt to get a true blind test evaluation, and therefore care was exercised in analyzing the data to attempt to simulate what would have been observed if only the first test result with one of the prototypes was used when more than one attempt was made to ascertain the purge system status. As this test program was part development testing and part evaluation testing of the devices, there were instances where multiple attempts were run with a prototype to attempt to match the purge condition shown by the roto-meter.

12 vehicles had inoperative purge systems in their as-received condition. 7 of the 12 vehicles with true failed purge systems could be identified visually by ATL’s experienced technicians. 5 of the 7 vehicles visually identified by ATL’s technicians were independently identified as visual failures by AZ I/M lane test technicians when the vehicles were returned to the I/M lane to receive their required state inspection test.

47 of 100 vehicles had plastic lines, or polymer lines which had become hard due to aging.

The evaluation results for average test time, testability, and accuracy are summarized in Table 1. Average test time is simply the arithmetic average of the test time recorded with each prototype on the as-received test. Testability statistics show the number of instances a slave hose was required to test either prototype. Accuracy statistics describe the number of times each prototype agreed with the determinations of the roto-meter, the reference method.

More detailed results of the as-received and induced failure tests are summarized in Appendix 1. Individual data sheets for each of the 100 vehicles which were analyzed to produce Table 1 and Table1-A of the Appendix, are presented in Appendix 5, and are available upon request.

Table 1
Summary Statistics

	EPA		Sensors	
Average Test Time	No.	Time, sec	No.	Time, sec
	46	144	47	164
Testability	No.	%	No.	%
Test Attempts	97		97	
Slave Hose Required	67	69	8	8
Accuracy	No.	%	No.	%
As-Received Vehicles - Purge Operating	88		88	
As-Received Vehicles - Tested with Prototype	85		81	
Correctly Identified	60	71	68	84
False Fail	25	29	13	16
As-Received Vehicles - Purge Not Operating	12		12	
As-Received Vehicles - Tested with Prototype	9		9	
Correctly Identified	9	100	8	89
False Pass	0	0	1	11
Induced Failure Tests	67		71	
Correctly Identified	63	94	64	90
False Pass	4	6	7	10

EPA Test Results

Timeliness - Total time was recorded for installing, entering data, initializing, testing, and removing the instrument. Average test time for 46 passing vehicles was about 2 minutes, 24 seconds.

Testability - 67 of 97 vehicles tested needed to add a slave line to install the two components of the EPA test device. The slave line used in this test program was 3/8 inch OD fuel line hose, and was spliced into the existing purge line designs by replacing the purge line with the longer slave line, or by adding the slave line in series with the existing purge line. In its current design, the purge line length required for installation of the EPA prototype was approximately seven inches of accessible, flexible purge line. The actual lengths of the slave hose used in this study were typically much longer than seven inches to allow more convenient underhood access.

As-Received Tests - 88 vehicles had purge flow as observed using the roto-meter, and 12 of the 100 vehicle sample had failed purge systems. 3 of those 12 vehicles had broken components and could not be tested with any method, including the roto-meter.

The EPA method correctly identified 60 passing vehicles, with 43 of the passing vehicles requiring slave hoses; 25 were false failures (29%) and 14 of the false failures were obtained using a slave hose; 3 vehicles could not be tested due to problems with the instrument's usage on a particular vehicle. These 3 vehicles are not included in the 25 false failures.

Of the 12 failures on the as-received tests, 9 could be tested with the roto-meter and EPA methods, and all 9 were correctly identified using the EPA method.

Induced Failure Tests - The EPA method was tested on 67 vehicles with induced failures, 63 of these correctly showed the no-flow condition, 4 were false passes (6%).

Overall Observations - The following observations and concerns were based on the results above, observations during testing conducted on January 6-8, daily phone conversations with ATL staff during the conduct of the evaluation, and in follow-up conversations with ATL during the week of February 1.

1) The operating principle of the method was demonstrated.

2) A high false fail rate (29%) was observed.

3) False pass (6%) was not a concern.

4) At over 2 minutes per test, not including the time to locate the purge line, and not including the vehicle operation time to induce purge, the prototype is not currently timely.

5) To avoid the use of a slave hose the ATL technicians recommended the EPA method be no larger than the size of an amperage probe (the combined size of both components including separation of the clamping and sensing components), which is similar in size to the clamp on a battery jumper cable, and is typically about 2 by 4

inches by 3/4 of an inch.

6) The method did not work on plastic or age/temperature hardened lines without a slave hose. (67 of 97 vehicles required slave lines.)

7) Part of the setup time comes from the need to manually adjust a threshold voltage for the sensing device due to differences in purge line diameter and hardness. Automating this operation seems necessary to reduce the total test time.

8) The method is sensitive to the orientation of the position of the clamping device and the load cell sensor, both the distance between them (getting the sensor too close to the clamp sometimes produced a false reading) and whether the clamp or sensor should be closest to the source of purge vacuum. For several tests, the orientation of the clamp and sensor needed to be reversed to obtain purge flow.

9) 4 vehicles produced notable changes in engine speed due to clamping and unclamping the purge line, which changes engine air flow and therefore engine speed. Changes in engine speed are qualitatively linked to exhaust emission effects and would not be acceptable during exhaust measurement.

10) 2 vehicles produced false results due to movement of the sensor caused by engine vibration related to misfire, or other vehicle specific reasons.

11) Purge lines less than or equal to 1/4 inch OD, found on Toyota Corollas for example, are too small to test in the device's current configuration.

12) The EPA method appears to lack sensitivity at the lower purge flow rates, such as less than 3-5 SCFH.

13) The durability of a strain gage method for high volume testing was not evaluated in this program.

Sensors Test Results

The evaluation of the Sensors device was also not a blind test because the status of the purge system was known by the presence of the roto-meter. As with the evaluation of the EPA device, sometimes more than one attempt was made by the test technician to obtain a valid reading, simply to see if minor adjustments with the prototype could result in obtaining the same result as the roto-meter result.

The Sensors device produced an indication of “pass” when the equivalent of 1.0 liter or greater of air and hydrocarbon mixture was measured on or before 240 seconds of engine operation. The observations summarized in Table 1 are based on the presence or absence of the “pass” indication on the computer monitor which also displays cumulative volume and instantaneous flow rate. The presence of voltage spikes during as-received tests can result in a false or premature pass condition, and during the induced failure mode, a false pass determination.

Timeliness - Using the same criteria for defining test time that was applied to the EPA method, the average test time for installing, entering data, initializing the test, obtaining the test result, and removing the device was about 2 minutes and 44 seconds.

Testability - 8 of 97 (8%) vehicles tested needed a slave line in which to insert the 0.040 in. diameter probe. Although not documented why a slave line was used with the Sensors method for a particular vehicle, the reasons may include: access to the purge line was still a problem on some vehicles, and some of the lines were plastic or age hardened, therefore requiring installation of a slave line. All 8 vehicles which used a slave line to test the Sensors device also needed the slave line for corresponding tests with the EPA device.

As-received Tests - The Sensors method correctly identified 68 vehicles with passing purge systems; 13 were false failures (16%); 7 vehicles could not be tested with the method due to instrument problems on specific vehicles. Consistent with the treatment of the EPA data, these 7 tests were not included in the 13 false failures.

9 true failures were evaluated with the Sensors method on as-received tests. One vehicle was incorrectly identified as a passing vehicle, and 8 were correctly identified.

Table 1-A of the Appendix indicates when a voltage spike was observed on the plot of instantaneous flow rate versus time. These results are coded with the letter V. In theory, the presence of one or more voltage spikes could produce a false "pass" reading. An examination of the Sensor's results shows that the presence of voltage spikes during as-received tests did not change the instrument's ability to correctly identify passing vehicles.

Induced Failure Tests - The Sensors method was tested on 71 vehicles; 7 vehicles showed false passes (10%). The presence of voltage spikes on induced failure tests had a notable impact. Had voltage spikes not been present on these tests, only 3 vehicles would have falsely passed (4%).

Overall Observations -

1) The operating principle of the method was demonstrated.

2) The voltage spike problem resulted in false determinations of "pass" on the induced failure tests.

3) A significant false fail rate (16%) was observed.

4) The method is not timely (164 seconds) in its current state.

5) A slave hose is generally not needed (8 of 97 vehicles) to test with the method.

6) The prototype did not use a centering method to assure the probe is located in the center of the flow stream. Development of such a technique is required to make the method timely and accurate.

7) No attempt was made to determine the adequacy of the silicone post treatment applied to a hole left by removing the probe after the test. Inserting a small probe such

as the 0.040 in. diameter needle in a purge line does not meet the definition of a non-intrusive test.

8) Needle durability was a problem with this prototype as at least 4 probes were required to complete the 100 vehicle test program.

Conclusions

EPA Test Device -

The following problem areas were most notable with the EPA prototype.

1) The prototype required a slave line to make a determination of purge flow due to plastic and age hardened lines on the vehicles' purge systems.

2) In its current design, the prototype is far too large to be used in the restricted configurations of real world vehicles' purge systems.

3) The prototype method is not timely.

4) False failure rates were high.

Items 1 and 2 above are severe limitations of the EPA prototype and it is unlikely that a second generation prototype would eliminate these problems. Without solving these problems, and proving success with a final prototype design in a high volume IM240 pilot study, I/M stakeholders are unlikely to be interested in the current EPA prototype.

Sensors Test Device -

The following problem areas were most notable with the Sensors prototype.

1) The intrusive nature of the method, and its unknown effects on purge system integrity and its possible effects when accidently applied to electrical lines and fuel lines, are significant concerns in a real world, high volume test environment, such as IM240 test programs.

2) An automated centering method is necessary for locating the probe.

3) The prototype method is not timely.

4) Probe durability is a problem with the prototype.

Item 1 is a significant problem that cannot be addressed by designing a second generation of prototype - inserting a probe into a purge line is fundamental to the method. Subsequent to the January evaluation, Sensors has met with EPA and stated that preliminary testing suggested that inserting and removing a 0.040 in. diameter probe in a sample of new and used purge lines did not show a leak was created with their test method. Even if that is correct, or a post treatment of the purge line were successfully demonstrated, the perception of the intrusive nature of this test, and its safety concerns in a high volume IM240 lane application, would likely prevent I/M stakeholders from being interested in this concept.

Other -

> 7 of 12 true failures of the purge system were identified visually by the experienced ATL technicians, and 5 of the 7 visual failures were found independently of this test program during the AZ I/M underhood inspection in the test lanes.

Recommendations

EPA Prototype -

Due principally to testability problems (the need to miniaturize the concept and concerns about hard purge lines which are common in older vehicles) and effects on engine speed during the exhaust test, it is not recommended that further effort be placed on additional development of this prototype.

Sensors Prototype -

Due to the intrusive nature of this flow measurement concept, it is not recommended that further effort be placed on additional development of this prototype.

Appendix 1
Results of Prototype Purge Flow Instrument Evaluation

Test results with the two prototypes are compared against readings obtained with the roto-meter. For all methods, a “1" indicates purge flow was measured and a “2" indicates no purge flow was measured. These values appear in the last six columns of Table 1. Two other numeric values appear in the last six columns of Table 1, a “3", or a “4". 3 was recorded where a test could not be run due to problems with a prototype that prevented it from being used for a particular vehicle. A 4 appears when no result was obtained due to a tampered or missing purge component on the vehicle. A 4 was also used to show a no-test result when a prototype device could not measure purge flow when it was detected with the roto-meter, and it was decided not to run a test with an induced failure because the prototype would likely have produced a correct failure reading, but only because the prototype was not operating correctly.

The letters “V”, “E”, “S”, and “SG” are used to provide further detail on the test results. The letter V is unique to the Sensors prototype, and shows where a voltage spike was observed on the plot of instantaneous flow versus time on the computer screen. The letter E appears on test results for vehicles 25 and 37. Engine vibration during a test appeared to have falsely influenced the purge status. The letter S was used to show which vehicles needed to have a slave purge line installed in order to test with either the EPA or the Sensors prototypes. SG appears on EPA results from vehicles 18, 23, 26, and 47 when the clamping and unclamping action of the piston assembly caused a change in engine RPM at a steady state condition.

Table 1-A
Results of Prototype Purge Flow Instrument Evaluation

Veh No.	Yr.	Make	Model	Odometer	Veh Type	As-Received Test Roto	As-Received Test EPA	As-Received Test Sens.	Induced Failure Test Roto	Induced Failure Test EPA	Induced Failure Test Sens.
1	88	Honda	Accord	116,051	LDV	1	2	1	2	3	2
2	85	Toyota	Celica	233,636	LDV	1	1	1	2	2	2
3	86	Olds.	Cutlass Sup.	128,731	LDV	1	1	1	2	2	2
4	90	Honda	Civic	120,706	LDV	1	2	3	2	3	3
5	89	Dodge	Dakota	93,436	LDT	1	1	1	2	2	2
6	84	Chev.	S-10 Blazer	122,420	LDT	1	1	1	2	2	1V
7	93	Mazda	B2000	11,224	LDT	1	1	1V	2	2	2
8	92	Nissan	Sentra	145,406	LDV	1	2S	2	2	2	2
9	86	Volvo	740 GLE	101,696	LDV	1	1S	1S	2	1	2
10	87	Nissan	Pickup	184,506	LDT	1	2	2	2	3	3
11	85	Buick	Century	102,095	LDV	1	1S	2	2	2	2
12	88	Pontiac	6000	112,599	LDV	1	1	1	2	2	1
13	88	Chev.	Berretta	105,030	LDV	1	1S	1S	2	2	1V
14	88	Pontiac	Grand Am	166,563	LDV	1	1S	1	2	2	2
15	89	Olds.	88	140,842	LDV	1	1S	1S	2	2	2
16	90	Dodge	Caravan	136,102	LDT	1	1S	3	2	2	3
17	85	Chev.	Cavalier SW	79,145	LDV	1	2S	1V	2	2	2
18	89	Nissan	240S	67,979	LDV	1	2S,SG	1	2	3	2
19	93	Ford	Escort SW	88,359	LDV	2	2	2	4	4	4
20	92	Toyota	Pickup	64,796	LDT	1	3	1	2	3	2
21	84	AMC	Eagle	96,884	LDV	1	1	1	2	2	1V
22	86	Mazda	B2000	64,415	LDT	1	1	1	2	2	1V
23	90	Buick	Century	80,201	LDV	1	1SG	1	2	2	2V
24	90	Chev.	S-10 Pickup	73,104	LDT	1	1S	1S	2	2	2
25	90	Isuzu	Amigo	125,984	LDT	1	1E	2	2	1	3
26	90	Nissan	Sentra	277,971	LDV	1	1SG	1	2	2	2V
27	85	Toyota	Pickup	212,781	LDT	1	3	1V	2	3	2
28	83	Jeep	Scrambler	129,790	LDT	4	4	4	4	4	4
29	91	Chev.	Pickup 1500	152,317	LDT	1	2S	1	2	2	2
30	94	Nissan	Pickup	82,497	LDT	1	2	3	2	3	3
31	89	Pontiac	Grand Prix	86,924	LDV	4	4	4	4	4	4
32	89	GMC	S-15	77,417	LDT	1	1S	1	2	2	1
33	87	Cadillac	Coupe DeVille	135,064	LDV	1	1S	1	2	2	2
34	84	Buick	Skyhawk	111,314	LDV	1	1S	1	2	2	2
35	86	Ford	Bronco	100,571	LDT	1	1S	1	2	2	2
36	89	Ford	Escort	48,883	LDV	1	1S	2	2	2	2
37	90	Jeep	Comanche	105,428	LDT	1	1S,E	2	2	1	3
38	91	Toyota	Tercel	121,267	LDV	1	2S	1	2	3	2

39	81	BMW	320 I	113,840	LDV	1	2S	1	2	2	2
40	85	Ford	Ranger	118,383	LDT	1	2	1	2	2	2
41	91	Geo	Storm	98,837	LDV	1	1	1	2	2	2
42	89	Jeep	Pickup	112,566	LDT	4	4	4	4	4	4
43	89	Mazda	626	52,891	LDV	1	2	1	2	3	2
44	89	Dodge	Spirit	129,973	LDV	1	2S	1	2	2	2
45	84	Honda	Civic	143,407	LDV	1	2S	1V	2	3	2
46	87	Volvo	740 Turbo	90,772	LDV	1	1S	1	2	2	2
47	91	Olds.	Cutlass Calais	148,627	LDV	1	1S,SG	1S,V	2	2	2
48	92	Geo	Storm	111,638	LDV	1	1	1V	2	2	2
49	88	Ford	Festiva LX	100,365	LDV	1	2S	3	2	3	3
50	87	Chev.	Celebrity	95,245	LDV	1	1	3	2	2	3
51	87	Chrysler	5th Avenue	137,873	LDV	1	2	1	2	3	2
52	93	Nissan	Quest	82,030	LDT	1	2	1	2	3	2
53	88	Suzuki	Samurai	99,939	LDT	1	3	1	2	3	2
54	89	Dodge	Grand Caravan	167,308	LDT	1	1S	1	2	2	2
55	85	GMC	S-15	150,122	LDT	2	2	2	4	4	4
56	83	Toyota	Corolla	63,905	LDV	1	1S	1	2	2	2
57	88	Toyota	Corolla SR5	111,581	LDV	1	1S	1V	2	2	2
58	94	Suzuki	Sidekick	70,011	LDT	1	1S	1	2	2	2
59	92	Plymouth	Grand Voyager	100,457	LDT	1	1S	1	2	1	2
60	85	Chrysler	5th Avenue	128,898	LDV	1	2S	1	2	3	2
61	90	Chev.	Lumina	98,402	LDV	2	2	2	4	4	4
62	93	Geo	Storm	106,289	LDV	1	2S	1V	2	3	1V
63	86	Chev.	Caprice Classic	39,672	LDV	2	2	2V	4	4	4
64	84	Ford	Mustang	157,225	LDV	2	2	2	4	4	4
65	91	Sterling	827 SL	83,163	LDV	1	1S	1	2	2	2
66	94	Chev.	S-10 Blazer	92,243	LDT	1	1	1V	2	2	2
67	89	Ford	Escort	130,661	LDV	1	1S	2	2	2	3
68	94	Chev.	S-10 Pickup	88,523	LDT	1	1S	1S	2	2	2
69	91	Ford	Ranger	97,083	LDT	1	2S	1V	2	2	2
70	90	Chev.	Lumina	140,765	LDV	2	2	2	4	4	4
71	94	Plymouth	Sundance	127,599	LDV	1	1S	1	2	2	2
72	90	Chev.	Lumina APV	135,380	LDT	1	1S	3	2	2	3
73	94	Toyota	Corolla	27,062	LDV	1	1S	3	2	2	3
74	87	Ford	Tempo	84,913	LDV	1	2	2	2	3	3
75	87	Cadillac	DeVille	65,951	LDV	1	1S	1	2	2	2
76	91	Chev.	S-10 Blazer	127,524	LDT	1	1S	1S	2	2	2
77	85	Toyota	SR5 Pickup	210,079	LDT	1	1S	1	2	2	2
78	93	Toyota	Pickup	80,101	LDT	1	1S	2	2	2	3
79	89	Mazda	MX 6	85,333	LDV	1	1S	1	2	2	2
80	89	Hyundai	Sonata	99,592	LDV	1	1S	1	2	2	2
81	89	Nissan	Pickup SE	40,028	LDT	1	2	1	2	3	2
82	83	Toyota	Pickup 4X4	131,791	LDT	2	2S	2	4	4	4
83	94	Ford	Explorer	72,921	LDT	1	1S	1	2	2	2
84	92	Ford	Explorer	67,087	LDT	1	1S	1	2	2	2
85	88	Mazda	B2200 Pickup	87,873	LDT	2	2S	2	4	4	4

86	**93**	**Toyota**	**Pickup 4X4**	**65,149**	**LDT**	**1**	**1S**	**1**	**2**	**2**	**2**
87	**90**	**Ford**	**Ranger XLT**	**116,195**	**LDT**	**1**	**1S**	**1**	**2**	**2**	**2**
88	**88**	**Mazda**	**MX 6**	**124,231**	**LDV**	**1**	**1**	**2**	**2**	**2**	**3**
89	**87**	**Nissan**	**300ZX**	**77,574**	**LDV**	**1**	**1S**	**1**	**2**	**2**	**2**
90	**90**	**Ford**	**Escort**	**104,012**	**LDV**	**1**	**1S**	**1**	**2**	**2**	**2**
91	**88**	**Mazda**	**B2200 Pickup**	**152,446**	**LDT**	**1**	**1S**	**1**	**2**	**2**	**2**
92	**88**	**Toyota**	**Celica**	**143,112**	**LDV**	**1**	**1S**	**1V**	**2**	**2**	**2**
93	**87**	**Toyota**	**Tercel**	**88,070**	**LDV**	**1**	**2S**	**2S**	**2**	**3**	**3**
94	**82**	**Volvo**	**240 Turbo**	**160,714**	**LDV**	**2**	**2S**	**2**	**4**	**4**	**4**
95	**91**	**Nissan**	**Pickup**	**100,276**	**LDT**	**1**	**2**	**2**	**3**	**3**	**3**
96	**85**	**Subaru**	**GL 4WD**	**110,062**	**LDT**	**1**	**1**	**1**	**2**	**2**	**2**
97	**86**	**Nissan**	**Sentra**	**155,826**	**LDV**	**1**	**1S**	**1V**	**2**	**2**	**2**
98	**92**	**Nissan**	**Sentra**	**107,788**	**LDV**	**1**	**2S**	**2**	**2**	**3**	**3**
99	**87**	**Nissan**	**Sentra**	**164,662**	**LDV**	**1**	**1S**	**1**	**2**	**2**	**2**
100	**89**	**Toyota**	**Camry**	**149,919**	**LDV**	**1**	**1S**	**1**	**2**	**2**	**2**

1 = Purge flow measured with 0-10 SCFH rotometer, or EPA, or Sensors instrument
2 = No purge flow measured with 0-10 SCFH rotometer, or EPA, or Sensors instrument
3 = No measurement due to instrument malfunction, or false fail on as-received test
4 = No measurement due to tampering of missing vehicle components, or true fail on as-received test
V = Voltage spike observed with Sensors instrument
E = Purge result may have been influenced by engine vibration
S = Slave line required to test EPA or Sensors instrument (as-received and induced fail modes)
SG = Engine surge noted during test with EPA instrument

Appendices 2-5 are available upon request from Martin Reineman, 734-214-4430, or e-mail address, Reineman.Martin@epa.gov