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Issue Paper

Cost effectiveness of a 2.0 g/test SHED Evaporative Standard for Light Duty Vehicles and Trucks

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Cost Effectiveness of a 2.0 g/test SHED Evaporative Standard for Light Duty Vehicles and Trucks

1. Statement of the Problem

What is the cost effectiveness of reducing light duty vehicle SHED evaporative emissions from a level of 6.0 g/test to 2.0 g/test?

2. Facts Bearing on the Problem

a. Exxon Research and Engineering Company conducted an evaporative test program under EPA Contract No. 68-03-2172[1]. In this study, six production vehicles which represented the four major U.S. manufacturers and two foreign manufacturers, were modifed in order to reduce evaporative emissions. Costs for the required modifications were then estimated. The resulting manufacturers' sales weighted retail price increase to achieve an evaporative level of less than 6 g/test on each vehicle was $2 per vehicle. The sales weighted retail price increase to achieve an evaporative level of less than 2.0 g/test on each vehicle was $3 per vehicle.

b. Automotive manufacturers have supplied evaporative emissions data on vehicles equipped with experimental control systems. Some of the vehicle test data submitted by GM, Ford and Chrysler were less than 2.0 g/test. The increase in vehicle retail price for these modifications was estimated based on Exxon's Contract No. 68-03-2172 cost estimates. From this information, the calculated sales weighted retail price increase (over 1976 production vehicles) to achieve the 2.0 g/test level was $7 per vehicle.

c. For the twenty production vehicles tested for evaporative emissions under Contract No. 68-03-2172, 83% of the emissions occurred during the hot-soak test and 17% during the diurnal test. For the six vehicles modified to an evaporative level of less than 2.0 g/test, 59% of the emissions occurred during the hot-soak and 41% during the diurnal.

3. Discussion

a. In the Exxon program, the vehicles which were eventually modified were also tested for evaporative emissions in their production configuration. In production form all six vehicles had evaporative emissions greater than 6.0 g/test. On most of these vehicles several different modifications were made during the test program. At some point in the program, the evaporative emissions from each vehicle decreased from a value above 6.0 g/test to a value of below 6.0 g/test. Based on the cost of these modifications, the retail increase required to achieve the 6.0 g/test level was estimated. As explained in reference (1), the estimated vehicle retail price increase for a certain modification

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[1] Clarke, P. J., "Investigation and Assessment of Light Duty Vehicle Evaporative Emission Sources and Control," Exxon Research and Engineering, EPA Contract # 68-03-2172, June 1976.

is assumed to be twice the cost to the manufacturer of that modification. The modifications performed on each vehicle and the estimated price increase are listed in Table I. As shown, the estimated retail price increase of the modifications ranged from $1.10 to $5.70. The resulting manufacturers' sales weighted average is $2[2]

After final modification, each of the six vehicles in the Exxon program had an evaporative emission level of less than 2.0 g/test. The retail price increase estimate was made and these are contained in Table II. As shown the retail price increase estimates ranged from $2.00 on the Ford to $25.20 on the Mazda. The cost on the Mazda consisted mainly of the underhood ventilating fan cost. Also worth mention is the fact that the costs for the Pontiac are those associated with the Vega canister system, not the ventilating fan system which was also tested.

On a manufacturer's sales weighted basis, the retail price increase to reduce evaporative emissions from the current production level to the 2.0 g/test level is $3 per vehicle. This value was calculated similarly to the 6.0 g/test cost as previously discussed. A detailed listing of the modifications and corresponding emission levels for each vehicle are contained in Attachments A-I through A-VI of Appendix A. Attachment VII of Appendix A summarizes the initial and final emission levels for the six vehicles.

b. Attachment B-I of Appendix B lists test results and information on ten experimental vehicles which have given SHED evaporative test results of less than 2.0 g/test. These vehicles were prepared and tested by their respective manufacturers. Data on the GM and Ford vehicles were supplied in response to California and Federal proposed evaporative regulations, and the Chrysler data was contained in Chrysler's, "Progress Report on Chrysler's Efforts to Meet the 1977 and 1978 Federal Emission Standards for HC, CO and NOx" (Dec. 1975). Using this information, along with the equipment cost information in Exxon's work under Contract No. 68-03-2172, the estimated vehicle retail price increase for the modifications on the vehicles listed in Table B-I has been calculated. This information is contained in Table III. As shown the cost of the modifications on these ten vehicles range from $0.50 for the Chrysler 6-cylinder vehicle to $13.25 for the Ford vehicles.

The Ford control system listed in Table III is the one that Ford has already developed to meet a 6 g/test standard. As indicated in Table III, Ford estimates the cost of this system as $15.00. This agrees quite well with the value of $13.25 which was obtained by summing the costs of the major components of the system. GM and Chrysler did not supply cost information for the modifications listed. Using the Ford cost estimate of $15.00 for the Ford system and the cost estimate as described above for the GM and Chrysler vehicles, the average costs of the GM, Ford, and Chrysler systems listed in the Table III are $3.75, $15.00 and $2.25 respectively. A sales weighted average of these costs

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[2] Based on sales data in "Automotive News Almanac," 1975 and "Automotive News," Mar. 22, 1976.

Table I. Summary of Vehicle Modifications and Costs in Achieving a 6.0 g/test Level (EPA Contract No. 68-03-2172)

Vehicle	Modifications		Cost, $
'75 Ford	Canister replacement with PCV purge		1.00
	Seal carburetor leak		0.30
	Barrier in air cleaner		0.20
	Air cleaner sealing		0.30
	Canister bottom cap		0.20
		Total	2.00
'75 Pontiac	Bowl vent to canister		0.50
	Seal carburetor leak		0.30
	Air cleaner sealing		0.30
		Total	1.10
'75 Chrysler	Canister replacement		4.00
	Canister bottom caps		0.40
	Bowl vent to canister		0.50
	Barrier in air cleaner		0.20
	Seal carburetor leak		0.30
	Air cleaner sealing		0.30
		Total	5.70
'74 Hornet	Seal carburetor leak		0.30
	Bowl vent to canister		0.50
	Air cleaner sealing		0.30
		Total	1.10
'74 Mazda	2 bowl vents to canister		1.00
	Canister installation		6.00
		Total	7.00
'74 Volvo	Canister replacement		1.00
	Heat shield between tank and muffler		1.00
		Total	2.00

Table II. Summary of Vehicle Modifications and Costs in Achieving a 2.0 g/test Level (EPA Contract No. 68-03-2172)

Vehicle	Modifications		Cost, $
'75 Ford	Canister replacement		1.00
	Seal carburetor leak		0.30
	Barrier in air cleaner		0.20
	Air cleaner sealing		0.30
	Canister bottom cap		0.20
		Total	2.00
'75 Pontiac	Bowl vent to canister		0.50
	Seal carburetor leak		0.30
	Air cleaner sealing		.30
	Canister replacement with PCV purge		1.20
		Total	2.30
'75 Chrysler	Canister replacement		4.00
	Canister bottom caps		0.40
	Bowl vent to canister		0.50
	Barrier in air cleaner		0.20
	Seal carburetor leak		0.30
	Air cleaner sealing		0.30
		Total	5.70
'74 Hornet	Seal carburetor leak		0.30
	Bowl vent to canister		0.50
	Air cleaner sealing		0.30
	Canister replacement with PCV purge		1.00
	Canister bottom cap		0.20
	Barrier in air cleaner		0.20
		Total	2.50
'74 Mazda	2 bowl vents to canister		1.00
	Canister installation with PCV purge		7.00
	Underhood ventilating fan		17.00
	Canister bottom cap		0.20
		Total	25.20
'74 Volvo	Canister replacement		1.00
	Heat shield between tank and muffler		1.00
		Total	2.00

Table III. Estimated Increase in Vehicle Retail Price for Manufacturer Designed and Tested Systems Which Have Yielded Evaporative Losses Less Than 2.0 g/test

No.	Vehicle Make	Modification	Cost, $
1	Oldsmobile	Dry canister (PCV purged)	0.60
		Sealed door in air cleaner snorkel	3.40(1)
		Bowl vented to canister	0.50
		Total	4.50
2	Chevelle	Vapor purge valve (PCV purged)	0.60
		Bowl vented to canister	0.50
		Internal vent closed (2-way bowl switch)	4.00(1)
		Total	5.10
3	Chrysler	2-way carburetor bowl vent switch	4.00
4	Chrysler	Bowl vented to canister	0.50
5 & 6	Ford	Bowl vent valve	3.00
		Enlarged canister	3.00
		PCV purged canister	0.60
		Auxiliary canister	3.00
		Electronic air cleaner door	3.40
		New gas cap	0.25
		Total	13.25 (15.00)(2)
7	Oldsmobile	Manually operated carb. bowl switch	3.00
8	Oldsmobile	Vacuum operated carb. bowl switch	3.00
9	Oldsmobile	Bowl vent to canister	0.50
		Door in air cleaner snorkel	3.40
		Total	3.90
10	Oldsmobile	Manually operated carb. bowl switch	3.00

(1) From manufacturers' comments on "Proposed Evaporative Emission Regulations for Light Duty Vehicles and Trucks", January 13, 1976.

(2) Ford's estimate for this system submitted to the EPA on February 27, 1976.

results in an estimated retail price increase (as calculated in Exxon's contract work) to reduce evaporative emissions from the current production level to 2.0 g/test of $7 per vehicle.

c. The cost-effectiveness of emission control strategies is commonly presented in units of dollars per ton of pollutant removed. To calculate such a cost-effectiveness for evaporative emission control, it is convenient to express the evaporative emission reduction in units of g/day and then g/mi. To calculate g/day, a relationship between the quantity of hot-soak and diurnal emission must be assumed. Based on Exxon test results under Contract No. 68-03-2172, it is assumed that vehicles at a 6 g/test level will emit 80% during the hot soak test and 20% during the diurnal; and vehicles at a level of 2 g/test will emit 60% during the hot-soak and 40% during the diurnal.

The above assumption, along with the assumption that the average vehicle undergoes 3.3 hot-soaks per day[3], results in evaporative hydrocarbon (HC) emissions of 17 g/day for a 6.0 g/test level vehicle, and 4.8 g/day for a 2.0 g/test vehicle. Assuming that the average vehicle travels 29.4 mi/day[3], the 6.0 g/test level vehicle and the 2.0 g/test vehicle emit 0.58 and 0.16 g/mi of HC evaporative emissions, respectively. The reduction in decreasing from 6.0 g/test to 2.0 g/test is 0.42 g/mi. Assuming a vehicle lifetime of 100,000 miles, this reduction in HC emission over the lifetime of the vehicle is 0.046 tons.

The contract work done by Exxon showed that the estimated sales weighted increase in vehicle retail price in going from a 6.0 g/test level to a 2.0 g/test level was $1. Estimating the associated reduction in HC emission over the life of the vehicle as 0.046 tons, the cost effectiveness is $22/ton.

The sales weighted cost estimate for the manufacturer's experimental systems which achieved 2.0 g/test was $7. This is $5 greater than the $2 cost of the Exxon modifications used to achieve a 6.0 g/test level. Assuming this $5 incremental cost, the cost effectiveness of going from 6.0 g/test to 2.0 g/test becomes $109/ton.

4. Summary

The cost effectiveness of removing HC emissions via reducing light duty vehicle and truck evaporative emissions from 6.0 g/test to 2.0 g/test has been estimated from both EPA contract study and manufacturers' supplied data. The cost effectiveness values obtained from these two sources of data are $22/ton and $109/ton, respectively. The true cost effectiveness of reducing evaporative emissions from 6.0 g/test to 2.0 g/test on a nationwide basis is expected to be between these two estimates.

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[3] "Compilation of Air Pollutant Emission Factors, Supplement 5", U.S. EPA, December 1975.

Appendix A

APPENDIX V

TABLE I

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Ford "LTD"
Year: 75
No.: 1
Displ. cu. in./Litre: 351/5.75

	Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a.	Purge from inside air cleaner element.		
b.	Barrier in air cleaner at base of snorkel.	6.1	
c.	Choke shaft passage sealed.		
II.	Steps a, b, c		
d.	Air horn to body gasket modified to allow more bowl vapors to be stored in air cleaner.	9.6	
III.e.	Purge to air cleaner snorkel as well as air cleaner.		

Measurements were made of purge rates for both an air cleaner and a snorkel purge system. Next, a curve of grams removed from canister vs. total purge volume was made. From these data it was estimated that a combination air cleaner-snorkel purge system would remove 13 to 15 grams from the canister during the SHED preconditioning period (4-LA-4s). This is not an adequate system because the combined diurnal and hot soak input to the canister is about 23 grams for the modified vehicle. Consequently, a PCV purge system was installed using a 1974 Vega canister which had been in daily usage up to this time.

	Modifications	Evap. Emissions, g/SHED Test	Remarks
IV.	PCV purge with Vega canister. The bottom of the canister is capped. An unmodified carburetor body to air horn gasket used along with modifications b and c above.	1.3 1.2	

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Attachment A-I

Table II

Summary of Evaporative Emissions from Modified Vehicles

Make: Pontiac
Year: 75
No. : 2
Displ. cu. in./Litre: 400/6.56

Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a. Vented carb. bowl to canister.		
b. Sealed leak around accel. pump shaft.	10.5 (diurnal)	
II. Steps a and b		Canister dried up before run.
c. Restriction in line from bowl to canister.	3.4	
III. Steps a, b, c		
d. Underhood ventilated with a fan.	1.6	Fan lowers carb. temp. about 30°F
e. Bottom on canister.	2.5	
	1.7	

NOTE: Upon completion of these tests, a Vega canister was installed, and tests were conducted without use of the underhood ventilating fan. Two repeat tests were performed and results were 1.52 and 1.75 g/test.

APPENDIX V

TABLE IV

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Chrysler
Year 75
No.: 21
Displ. cu. in./Litre: 440/7.21

Modifications	Evap. Emissions, g/SHED Test	Remarks
I Original ECS	13.4	Diurnal - 6.3 g, H.S. - 7.1 g
Original ECS	14.6	Diurnal - 4.4 g, H.S. - 10.2 g
II Modified ECS:		
(a) Two canisters in parallel used (b) Second carb. bowl vented directly to canister (c) Bottom on each canister (d) Barrier at base of snorkel (e) Accel. pump shaft leak sealed	1.9 2.0	

APPENDIX V

TABLE V

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Hornet
Year: 74
No.: 11
Displ. cu. in./Litre: 232/3.80

	Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a.	Carb. bowl vented to the canister.	3.9	
b.	Accel. pump shaft leak sealed.		
II.	Steps a and b above - restriction in line from carb. bowl to canister.	3.1	
c.	Barrier installed in air cleaner at base of snorkel.		
III.	Steps a, b, c above		
d.	Bottom of canister closed.	2.5	
IV.	ECS modified to a PCV purge system using a 1974 Vega canister. Steps a, b, c, and d above also continued.	1.2 1.3	

APPENDIX V

TABLE VI

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Mazda
Year: 74
No.: 15
Displ. Cu In./Litre: 80/1.31 (Rotary)

Step	Modifications	Evap. Emissions g/SHED Test	Remarks
I	Both carburetor bowls vented to a 3 tube canister (Chrysler). Purge is through existing purge line to PCV. Original ECS used for diurnal.	4.8, 3.8	Hydrocarbon vapors escaping from snorkel.

II Next, the modifications indicated below were tested. In each case, the hydrocarbon level from the SHED test exceeded 2.0 grams.

1. Canister moved outside of engine compartment to a cooler environment.
2. Canister dried up on vacuum pump prior to diurnal and hot soak.
3. Air cleaner canister closed off and 3 tube canister used for both diurnal and hot soak.

At this point, additional source determination tests indicated hydrocarbon vapors emanating from carburetor throat due to fuel drippage. To alleviate pressure in the carburetor bowl, a fan installed to lower bowl temperature by ventilating the underhood engine compartment.

Step	Modifications	Evap. Emissions g/SHED Test	Remarks
III	Modifications for Step I. Underhood fan to ventilate underhood.	2.8	

At this point, the 3 tube canister was changed to a 4 tube Vega with a purge control valve. (Used canister from 1974 Vega.) High diurnal losses in above runs due to tank vapors passing into engine crankcase, then through PCV purge line into 3 tube canister. Vapors then moved out of the canister into the carburetor bowl and air cleaner through the vent line from the bowl to the canister. The purge control valve prevents this migration of vapors into the carburetor bowl and air cleaner.

Step	Modifications	Evap. Emissions g/SHED Test	Remarks
IV	Modifications for Step I with exception of replacing 3 tube canister with a 4 tube unit. Fan to ventilate underhood.	1.8, 1.3	

APPENDIX V

TABLE VII

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Volvo
Year: 74
No.: 17
Displ. cu. in./Litre: 121/1.98

	Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a.	Equalizing valve modified so as to relieve fuel tank pressure at 0.5 psig.	0.4	CO and HC exhaust levels higher with modified ECS.
b.	Baffle installed between fuel tank and muffler.		
c.	American Motors canister used.	1.7	

TABLE II. SHED Evaporative Tests on Vehicles Tested Under Contract No. 68-03-2172.

Vehicle	Engine	ECS Condition	Evaporative Emissions, g: No. of Tests	Average Diurnal	Average H. Soak	Total: Range	Total: Average	Exhaust Emissions, g/mi[1]: HC	CO	NOx
'75 Ford	351-2bbl	Stock	2	3.4	3.2	6.2 -7.1	6.7	0.54	6.75	1.62
		Modified	2	0.2	1.0	1.2 -1.3	1.2	0.52	4.44	1.87
'75 Pontiac	400-4bbl	Stock	2	0.4	7.1	7.2 -7.8	7.5	0.80	6.95	1.31
		Modified	3	1.2	0.7	1.6 -2.5	1.9[2]	0.68	4.05	1.36
'74 AMC	232-1bbl	Stock	2	0.5	10.3	10.8 -10.8	10.8	1.50	24.5	1.24
		Modified	2	0.3	0.9	1.2 -1.3	1.2	1.51	26.9	1.13
'74 Mazda	80-4bbl	Stock	2	0.2	10.4	10.5 -10.7	10.6	2.11	11.7	0.88
		Modified	2	0.6	0.9	1.3 -1.8	1.5	1.82	9.90	0.65
'74 Volvo	121-FI	Stock	2	4.7	3.2	7.1 -8.7	7.9	0.91	13.3	2.15
		Modified	2	0.7	0.4	0.4 -1.7	1.1	1.24	22.6	1.58
'75 Chrysler	440-4bbl	Stock	2	5.3	8.6	13.4 -14.6	13.9	2.32	23.2	1.98
		Modified	2	0.6	1.3	1.9 -2.0	1.9	1.10	13.3	1.83

(1) Average of 2 or more tests

(2) This data is for an underhood ventilating fan system. A PCV-purged canister system was later tested on this vehicle and average 1.6 g/test for 2 tests.

Appendix B

TABLE III. Manufacturer's SHED Evaporative Tests on Experimental Control Systems.

Vehicle No.	Make	Engine, CID	Carburetor	No. of Tests	Average Emissions, g Diurnal	Hot Soak	Total
1	Oldsmobile(1)	455	4 bbl	1	0.33	1.17	1.50
2	Chevelle(2)	250	1 bbl	1	0.64	1.23	1.87
3	Chrysler(3)	318	2 bbl	1	0.42	1.31	1.78
4	Chrysler(4)	225	1 bbl	7	0.72	1.05	1.78
5	Ford(5)	302	-	3	-	-	1.45
6	Ford(5)	400	-	3	-	-	1.54
7	Oldsmobile(6)	455	4 bbl	1	0.85	1.07	1.92
8	Oldsmobile(7)	455	4 bbl	1	0.74	0.96	1.70
9	Oldsmobile(8)	-	-	1	0.80	0.92	1.72
10	Oldsmobile(9)	-	-	2	0.48	1.18	1.66

(1) Dry canister, closed air cleaner snorkel during hot soak and float bowl vented to canister.
(2) Vapor purge valve, float bowl vented to canister and internal vent closed.
(3) 2-way carburetor bowl vent.
(4) Carburetor bowl vent to canister.
(5) Bowl vent valve, PCV purged enlarged canister, auxiliary canister, electronic air cleaner door and new gas cap.
(6) Proposed production ECS design with manually operated carburetor bowl switch.
(7) Proposed production ECS design with vacuum operated carburetor bowl switch.
(8) Experimental V-8 engine with bowl vent and air cleaner door, 1978 prep.
(9) Experimental V-8 engine with manual bowl vent switch, 1976 prep.

APPENDIX to the ANALYSIS OF COMMENTS