76-13 GS

The Mark II Vapor Injector: An Air-Vapor Bleed Device Evaluated

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Technology Assessment and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Environmental Protection Agency

Background

The APO Mark II Vapor Injector marketed in the United States by APO of America, Inc., Dallas, Texas is essentially an induction system air-vapor bleed device. It is the fifth device of this basic type to be tested by TAEB in the past five years.[1,2,3,4] The general conclusions of the four previous air-vapor bleed device tests were that fuel economy improvements if any, were small and were attributed to enleanment of the air fuel mixture as opposed to the effects of the added vapors. Similarly exhaust emissions changes were minor and were typical of the results of enleanment of air-fuel ratios near stoichiometry. The Mark II contains several variations on the basic vapor bleed device theme which could alter its performance relative to other devices of this type. In light of these variations and an interest in the Mark II exhibited by the public and some sectors of the government, EPA evaluated the device.

The Environmental Protection Agency receives information about many devices for which emission reduction or fuel economy improvement claims are made. In some cases, both claims are made for a single device. In most cases, these devices are being recommended or promoted for retrofit to existing vehicles although some represent advanced systems for meeting future standards.

The EPA is interested in evaluating the validity of the claims for all such devices, because of the obvious benefits to the Nation of identifying devices that live up to their claims. For that reason the EPA invites proponents of such devices to provide to the EPA complete technical data on the device's principle of operation, together with test data on the device made by independent laboratories. In those cases in which review by EPA technical staff suggests that the data submitted hold promise of confirming the claims made for the device, confirmatory tests of the device are scheduled at the EPA Emissions Laboratory at Ann Arbor, Michigan. The results of all such confirmatory test projects are set forth in a series of Technology Assessment and Evaluation Reports, of which this report is one.

The conclusions drawn from the EPA confirmatory tests are necessarily of limited applicability. A complete evaluation of the effectiveness of an emission control system in achieving its claimed performance improvements on the many different types of vehicles that are in actual use requires a much larger sample of test vehicles than is economically feasible in the confirmatory test projects conducted by EPA.[5] For promising devices it is necessary that more extensive test programs be carried out.

The conclusions from the EPA confirmatory tests can be considered to be quantitatively valid only for the specific type of vehicle used in the EPA confirmatory test program. Although it is reasonable to extrapolate the results from the EPA confirmatory test to other types of vehicles in a directional or qualitative manner, i.e., to suggest that similar results are likely to be achieved on other types of vehicles, tests of the device on such other vehicles would be required to reliably quantify results on other types of vehicles.

In summary, a device that lives up to its claims in the EPA confirmatory test must be further tested according to protocols described in footnote 5, to quantify its beneficial effects on a broad range of vehicles. A device which when tested by EPA does not meet the claimed results would not appear to be a worthwhile candidate for such further testing from the standpoint of the likelihood of ultimately validating the claims made. However, a definitive quantitative evaluation of its effectiveness on a broad range of vehicle types would equally require further tests in accordance with footnote 5.

System Description

The Mark II Vapor Injector is a device for inducting an air-vapor mixture into the intake system of the conventional spark ignited gasoline engine. The point of induction can be the Positive Crankcase Ventilation (PCV) line, a spacer plate installed between the carburetor and the intake manifold, or an idle adjustment screw with a hole through the center. The latter method was chosen for this evaluation because the previous evaluations used the PCV induction point. The spacer plate is essentially the same as the PCV induction point.

The Mark II consists of a large glass jar approximately two-thirds full of a fluid comprised of one part Mark II Econo Mix fluid and two parts water. Air is drawn in through a brass needle valve mounted on the cast aluminum jar cap, and passes through a plastic tube to a plastic bubbler located near the bottom of the jar. After bubbling through the fluid, the resulting air-vapor mixture is drawn out of the bottle through a vacuum hose connected to the jar cap. A .022 inch diameter metering orifice mounted in the vacuum hose restricts the flow of air-vapor mixture to the Vapor Jet, an idle adjustment screw with a hole drilled through the center. The air-vapor mixture is drawn through the Vapor Jet by manifold vacuum. A check valve in the Vapor Jet is intended to prevent reversal of flow.

Figure 1 is a photograph of the Mark II as installed in the vehicle used in this evaluation, a 1971 Chevrolet Vega. As the Mark II is "driven" by manifold vacuum the volume of vapor delivered to the intake manifold is virtually independent of engine displacement. To maximize the effect of the device, a vehicle with a small displacement engine was selected. Table 1 is the vehicle description of the Vega. Figure 2 is a schematic of the Vega carburetor with the Vapor Jet installed.

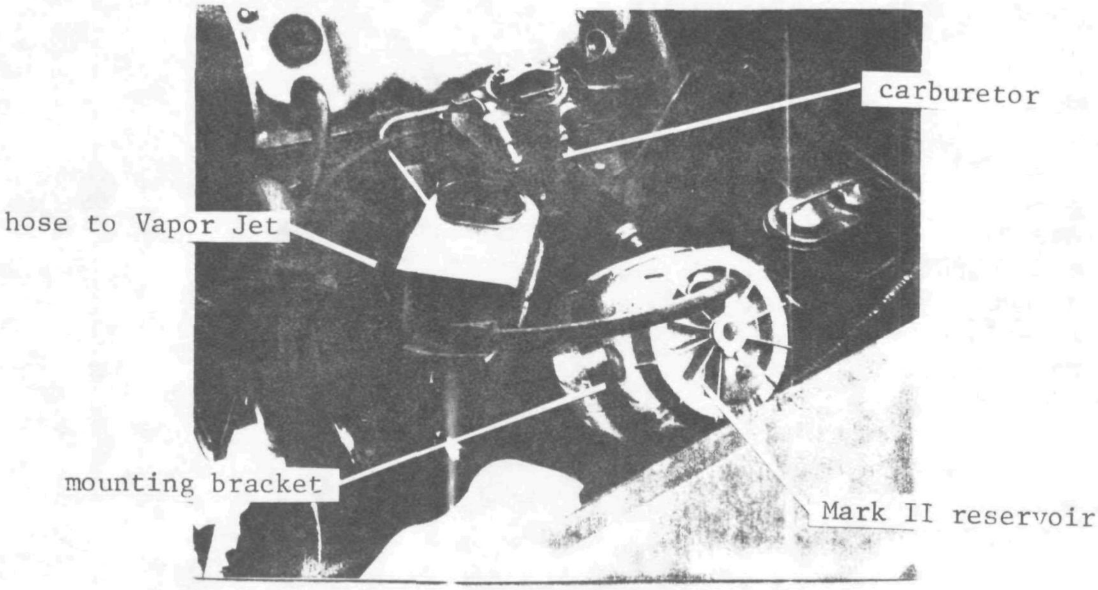

Figure 1 Mark II installation on 1971 Vega (air cleaner removed).

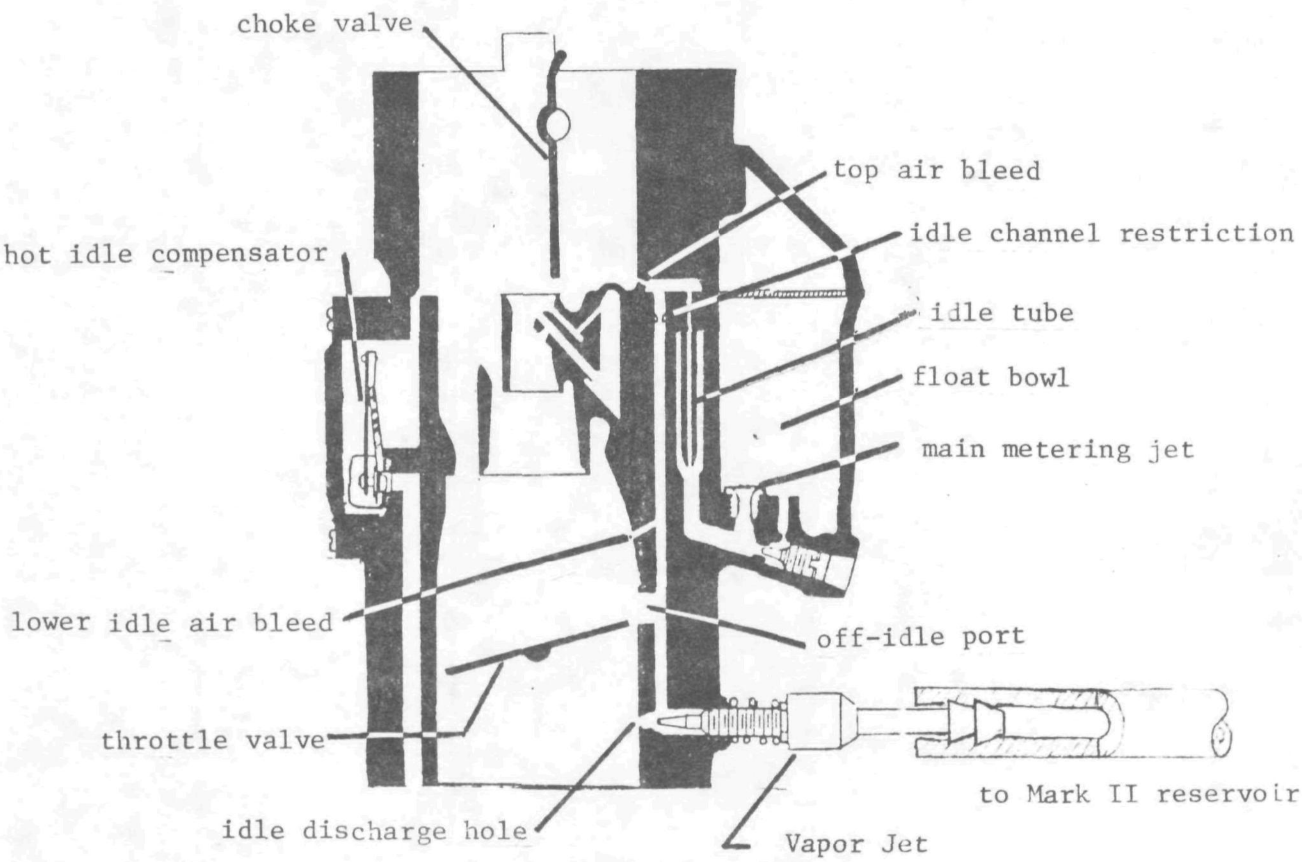

Figure 2 Schematic of Vega carburetor showing idle circuitry with Mark II Vapor Jet installed.

Table 1

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1971 Chevrolet Vega Kammback
Emission control system - PCV

Engine

type	4 cyl. OHC
bore x stroke	3.50 x 3.625 in./88.9 x 92.1 mm
displacement	140 CID/2300 cc
compression ratio	8.0:1
maximum power @ rpm	90 hp/67 kW @ 4400 rpm
fuel metering	1 barrel
fuel requirement	91 RON

Drive Train

transmission type	3 speed manual
final drive ratio	2.53

Chassis

type	front engine, rear drive, unitized body
tire size	A 78 x 13
curb weight	2340
inertia weight	2750
passenger capacity	4

Emission Control System

basic type	PCV
mileage at beginning of test program	11,000 miles

According to Mr. Allen Best, the technical advisor of APO, the composition of the Econo Mix by volume is 65% methanol, 34% acetone, and 1% propylene glycol. The benefits of the vapors of Econo Mix-water mixture claimed in the Mark II owner's manual are a decrease in required octane number of the gasoline used, increased fuel economy, increased power, elimination of carbon deposits, extension of engine life, and reduction of exhaust emissions. EPA evaluates devices in terms of their effects on vehicle emissions, fuel economy, and occasionally performance. Additions of methanol and water to gasoline are known to increase the octane number of fuel and additions of methanol under certain conditions to increase power. Therefore, it was felt desirable to conduct a preliminary evaluation of the possible benefits of the APO device based on information available in the technical literature concerning the various constituents of the APO fluid and measurements of the operating variables of the device. This evaluation is presented in Appendix I.

Test Procedure

Exhaust emissions tests were conducted according to the 1975 Federal Test Procedure ('75 FTP), described in the Federal Register of November 15, 1972, and the EPA Highway Fuel Economy Test (HFET), described in the Federal Register, Volume 39, Number 200, October 15, 1974. Both of these tests are conducted on a chassis dynamometer and employ the Constant Volume Sampling (CVS) procedure, which gives exhaust emissions of HC, CO, NO_x and CO_2 in grams per mile. Fuel economy is calculated by the carbon balance method. The fuel used was Indolene unleaded 96 RON gasoline.

The vehicle was tested in three different configurations: baseline, with the Mark II installed but without any fluid in the jar, and with the Mark II functioning with fluid. The second configuration was tested in order to separate the effect of the fluid vapors from the effect of the air bleed.

Before the baseline testing, the vehicle was tuned to manufacturer's specifications. The carburetor idle mixture adjustment was adjusted to lean best idle, which for this vehicle resulted in a 0.2% idle CO. The idle mixture was adjusted to lean best idle after the installation of the Mark II in each configuration tested. In both cases the idle CO was again 0.2%.

The test schedule plan was two '75 FTP's and two HFET's for each of the following test conditions:

1. Baseline
2. Mark II installed but without fluid
3. Mark II with fluid
4. Mark II with fluid after 1500 miles of operation on the durability driving schedule described in the Federal Register Vol. 37, No. 221, November 15, 1972
5. Mark II without fluid after mileage accumulation
6. Baseline after mileage accumulation

Due to difficulties encountered in the test program additional tests were conducted as discussed in the following section.

Test Results

The test schedule was initially conducted according to plan with some additional tests being conducted to increase confidence in the data. After the 1500 miles, the idle specifications were again set to manufacturer's specification. The two tests following this idle tune had '75 FTP and HFET fuel economy decreases of 8 and 16 percent respectively from the baseline data. Inspection of the vehicle revealed the distributor vacuum line disconnected at the carburetor. The exact time when the vacuum hose was disconnected is not known but it is our belief that the hose was not reconnected during the idle timing check after the mileage accumulation. The results of the above two tests were discarded, the hose was reconnected, and the tests were repeated. Subsequent tests displayed a steady increase in hydrocarbon emissions apparently independent of the test configuration. Concurrent with the hydrocarbon increases was a smaller but still discernible decrease in fuel economy.

Thorough diagnostics revealed low compression in number two cylinder (120 psi vs. 180 psi for the other three cylinders). The head was removed and the exhaust valve of the number two cylinder was observed to be mildly burned due to valve seat warpage. In retrospect it is possible that operating the vehicle with the vacuum leak and no vacuum advance contributed to the valve seat warpage. This valve was replaced and the valve seat ground; great care was taken not to disturb the deposits on the head. After the head was replaced, the car was driven approximately 150 miles with the Mark II functioning. A second series of "after mileage accumulation" tests were run. These are identified alternatively as "after valve replacement" or "after 2,000 miles," as opposed to the original "after 1,500 miles."

The composite results of the '75 FTPs are presented in Table 2; detailed individual bag results are given in Appendix II. The HFET results are given in Table 3. Figures 3 and 4 display the fuel economy values of the '75 FTPs and HFET's respectively. Figure 5 displays the hydrocarbon, carbon monoxide and nitrogen oxides emissions of the '75 FTPs. Three tests (16-1280, 76-1310 and 76-2455) were not included in these Figures because they were determined to be statistically invalid using the Dixon method[6] on the CO_2 data.*

The representatives of the Mark II claim that the device cleans the engine and that it is only after mileage accumulation that the true effects of the device can be measured. Therefore the effect of the exhaust valve-to-seat seal deterioration on the long term effects of the Mark II must be addressed. First, as evidenced in Figure 5 the change in HC emissions, which are indicative of the leak, did not increase until after the mileage accumulation was completed. Thus the mileage accumulation can be assumed to have occurred normally. Second, when the HC emission increased from approximately 1.7 to 2.7 grams per mile (gpm) the fuel economy decreased only 4 to 5 percent and the other gaseous emissions remained virtually unchanged. This indicates that the loss in compression in the one cylinder was relatively minor and that the cylinder continued to fire normally. Again the operation of the Mark II was not

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* Only the tests before mileage accumulation and after the valve replacement were considered because the remaining tests were taken on a malfunctioning engine, as evidenced by the steadily increasing hydrocarbon emissions, which was remedied by the valve replacement.

Figure 3
'75 FTP Composite Fuel Economies
by individual test

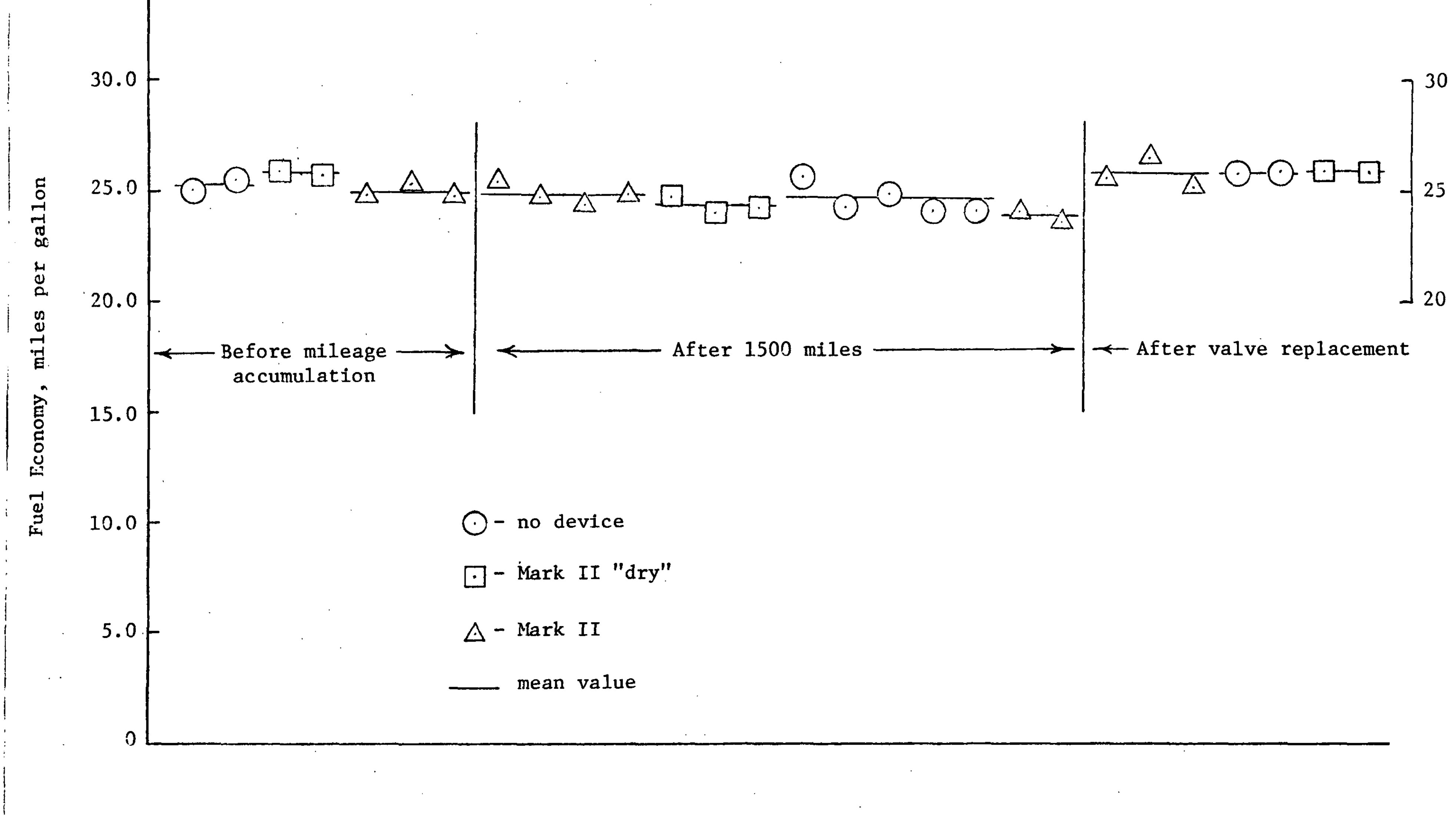

Figure 4
Highway Cycle Fuel Economies
by individual test

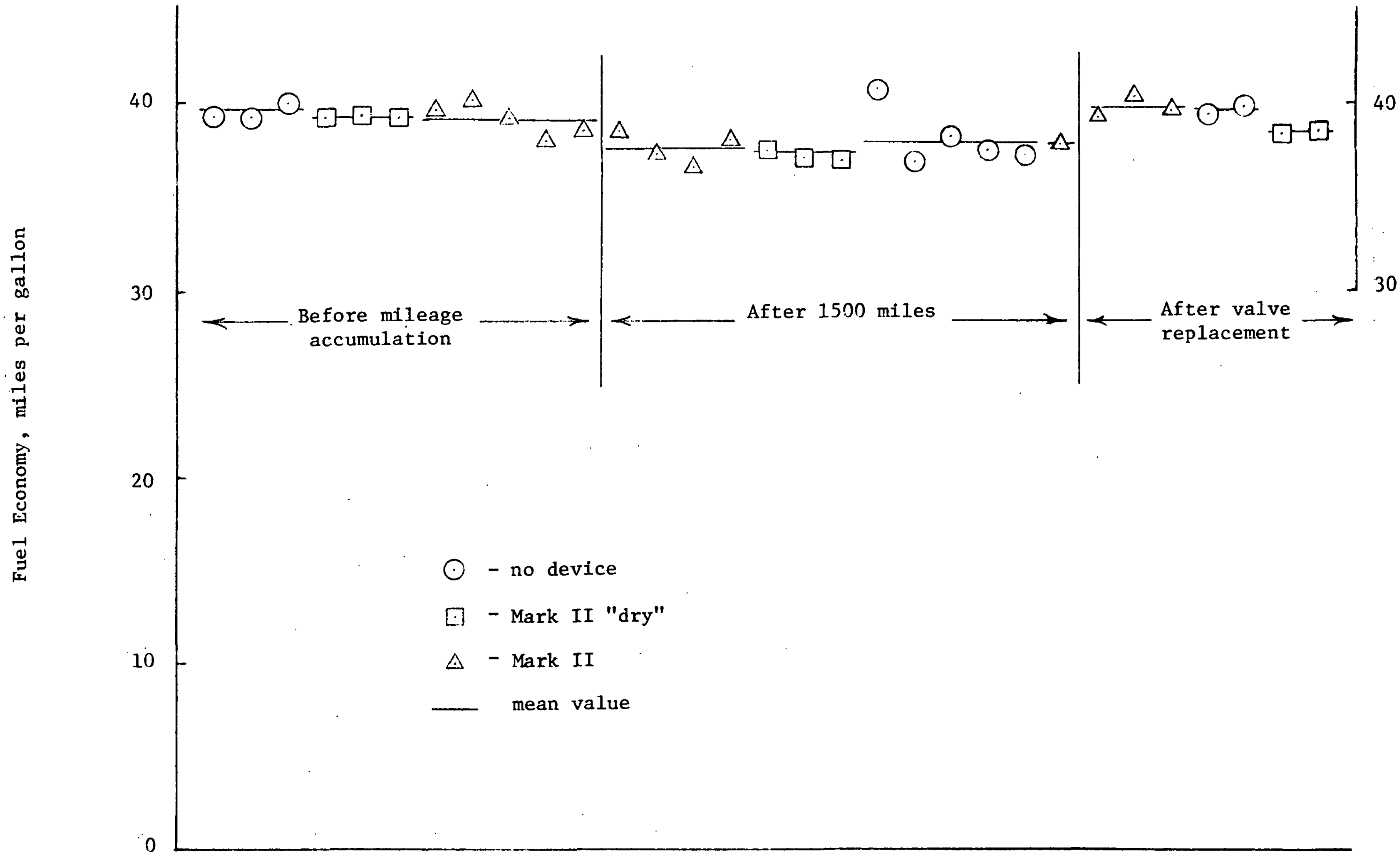

Figure 5
'75 FTP Composite Emission
by individual test

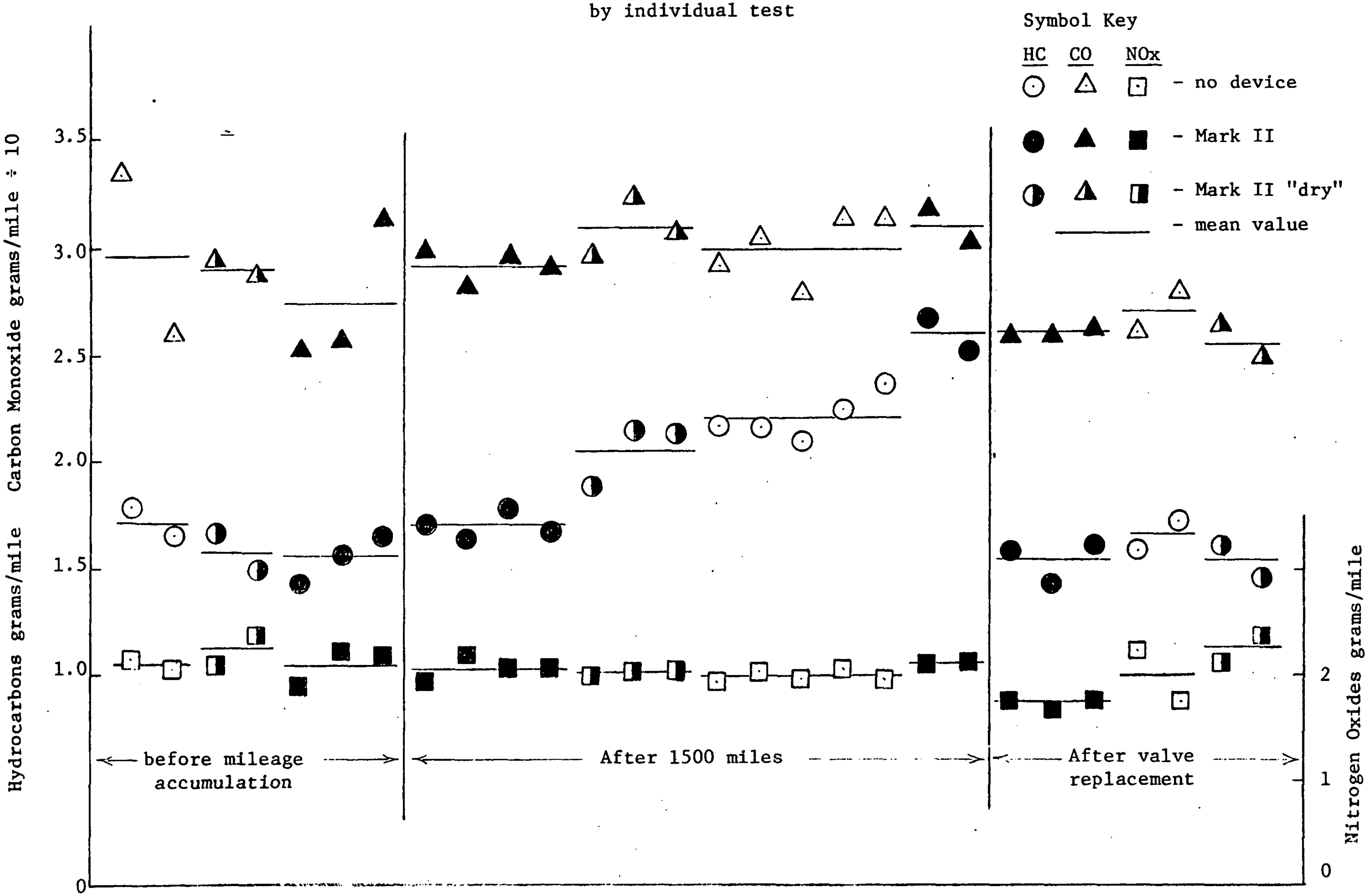

Table 2

'75 FTP Composite Results
Mass Emissions, grams per mile (grams per kilometer)
Fuel Economy, miles per gallon (liters per 100 kilometer)

Test Configuration	HC		CO		CO_2		NOx		Fuel Economy	
Before mileage accumulation										
no device	1.77	(1.10)	33.4	(20.8)	295	(183)	2.12	(1.32)	25.1	(9.37)
"	1.65	(1.03)	25.8	(16.0)	302	(188)	2.04	(1.27)	25.5	(9.23)
Mark II "dry"	1.66	(1.03)	29.4	(18.3)	292	(181)	2.08	(1.29)	25.8	(9.12)
"	1.48	(0.92)	28.6	(17.8)	296	(184)	2.35	(1.46)	25.7	(9.16)
Mark II	1.43	(0.89)	25.2	(15.7)	314	(195)	1.87	(1.16)	24.8	(9.49)
"	1.56	(0.97)	25.7	(16.0)	305	(190)	2.21	(1.37)	25.3	(9.30)
"	1.65	(1.03)	31.3	(19.5)	305	(190)	2.15	(1.34)	24.7	(9.53)
After 1500 miles										
Mark II	1.70	(1.06)	29.9	(18.6)	297	(185)	1.93	(1.20)	25.4	(9.26)
"	1.64	(1.02)	28.5	(17.7)	309	(192)	2.17	(1.35)	24.7	(9.53)
"	1.78	(1.11)	29.6	(18.4)	311	(193)	2.05	(1.27)	24.4	(9.64)
"	1.67	(1.04)	29.1	(18.1)	306	(190)	2.03	(1.26)	24.8	(9.49)
Mark II "dry"	1.88	(1.17)	29.7	(18.5)	306	(190)	1.99	(1.24)	24.7	(9.53)
"	2.15	(1.34)	32.3	(20.1)	311	(193)	2.02	(1.26)	24.0	(9.80)
"	2.13	(1.32)	30.6	(19.0)	311	(193)	2.03	(1.26)	24.2	(9.72)
no device	2.17	(1.35)	29.2	(18.1)	292	(181)	1.93	(1.20)	25.7	(9.16)
"	2.16	(1.34)	30.4	(18.9)	311	(193)	2.02	(1.26)	24.3	(9.68)
"	2.10	(1.31)	27.8	(17.3)	306	(190)	1.97	(1.22)	24.9	(9.45)
"	2.25	(1.40)	31.3	(19.5)	310	(193)	2.05	(1.27)	24.2	(9.72)
"	2.37	(1.47)	31.3	(19.5)	310	(193)	1.95	(1.21)	24.2	(9.72)
Mark II	2.68	(1.67)	31.8	(19.8)	310	(193)	2.09	(1.30)	24.1	(9.76)
"	2.53	(1.57)	30.3	(18.8)	320	(199)	2.11	(1.31)	23.6	(9.97)
After valve replacement										
Mark II	1.47	(0.91)	27.6	(17.2)	331	(206)	1.96	(1.22)	23.4	(10.1)
"	1.58	(0.98)	26.0	(16.2)	301	(187)	1.76	(1.09)	25.6	(9.19)
"	.84	(0.52)	23.1	(14.4)	268	(167)	1.43	(0.89)	28.9	(8.14)
"	1.43	(0.89)	26.0	(16.2)	290	(180)	1.68	(1.04)	26.5	(8.88)
"	1.61	(1.00)	26.2	(16.3)	306	(190)	1.76	(1.09)	25.2	(9.34)
no device	1.59	(0.99)	26.1	(16.2)	298	(185)	2.21	(1.37)	25.8	(9.12)
"	1.73	(1.08)	28.0	(17.4)	293	(182)	1.75	(1.09)	25.9	(9.08)
Mark II "dry"	1.61	(1.00)	26.4	(16.4)	296	(184)	2.10	(1.31)	25.9	(9.08)
"	1.46	(0.91)	24.9	(15.5)	299	(186)	2.35	(1.46)	25.9	(9.08)

Table 3

Highway Cycle Results
Mass emissions, grams per mile (gram per kilometer)
Fuel economy, miles per gallon (liters per 100 kilometer)

Test configuration	HC	CO	CO_2	NOx	Fuel economy	Temp. °F	Rel. hum. %	Baro. P. " Hg
Before mileage accumulation								
Mark II	0.91 (0.57)	8.97 (5.57)	207 (129)	3.55 (2.21)	39.6 (5.94)	68.0	76	28.57
"	0.88 (0.55)	8.40 (5.22)	205 (127)	3.32 (2.06)	40.1 (5.87)	68.0	61	28.50
"	0.88 (0.55)	9.16 (5.69)	210 (131)	3.37 (2.09)	39.1 (6.02)	68.0	61	28.48
Mark II "dry"	0.90 (0.56)	8.10 (5.03)	211 (131)	3.33 (2.07)	39.2 (6.00)	65.5	64	28.46
"	0.91 (0.57)	8.12 (5.05)	210 (131)	3.32 (2.06)	39.3 (5.99)	66.0	52	28.47
"	0.90 (0.56)	8.46 (5.26)	210 (131)	3.40 (2.11)	39.2 (6.00)	66.0	58	28.46
no device	0.88 (0.55)	8.30 (5.16)	210 (131)	3.41 (2.12)	39.3 (5.99)	68.0	55	28.48
"	0.88 (0.55)	8.31 (5.16)	206 (128)	3.36 (2.09)	39.9 (5.90)	65.0	52	28.48
"	0.88 (0.55)	8.02 (4.98)	206 (128)	3.38 (2.10)	40.0 (5.88)	66.0	58	28.44
Mark II	0.75 (0.47)	5.84 (3.63)	222 (138)	3.86) (2.40)	37.9 (6.21)	65.5	45	29.34
"	0.86 (0.53)	7.55 (4.69)	221 (137)	3.77 (2.34)	37.7 (6.24)	69.0	55	28.83
After 1500 miles								
Mark II	0.89 (0.55)	9.66 (6.00)	213 (132)	3.32 (2.06)	38.4 (6.13)	70.5	42	28.91
"	0.87 (0.54)	7.88 (4.90)	223 (139)	3.66 (2.27)	37.2 (6.33)	72.0	44	29.09
"	0.92 (0.57)	8.60 (5.34)	227 (141)	3.64 (2.26)	36.5 (6.45)	66.5	51	29.01
"	0.91 (0.57)	8.75 (5.44)	217 (135)	3.32 (2.06)	38.0 (6.19)	65.0	52	28.84
Mark II "dry"	0.89 (0.55)	7.78 (4.84)	222 (138)	3.44 (2.14)	37.4 (6.29)	70.5	47	29.16
"	0.96 (0.60)	9.62 (5.98)	222 (138)	3.46 (2.15)	37.0 (6.36)	68.0	53	28.98
"	1.00 (0.62)	10.10 (6.28)	222 (138)	3.25 (2.02)	36.8 (6.39)	71.0	53	28.99
no device	0.93 (0.58)	7.15 (4.44)	204 (127)	3.06 (1.90)	40.6 (5.80)	69.0	47	29.18
"	1.00 (0.62)	8.30 (5.16)	224 (139)	3.38 (2.10)	36.9 (6.38)	71.0	46	28.98
"	1.02 (0.63)	8.66 (5.38)	216 (134)	3.04 (1.89)	38.2 (6.16)	73.5	43	28.70
"	1.03 (0.64)	10.18 (6.33)	225 (140)	3.55 (2.21)	36.4 (6.46)	70.0	46	28.75
"	1.13 (0.70)	8.55 (5.31)	222 (138)	3.55 (2.21)	37.2 (6.33)	70.0	49	28.98
Mark II	1.01 (0.63)	6.92 (4.30)	220 (137)	3.55 (2.21)	37.9 (6.21)	73.0	44	29.25
After valve replacement								
Mark II	0.81 (0.50)	9.10 (5.66)	236 (147)	3.07 (1.91)	35.1 (6.70)	77.0	56	29.12
"	0.88 (0.55)	8.01 (4.98)	211 (131)	3.04 (1.89)	39.2 (6.00)	71.0	49	29.07
"	0.36 (0.22)	7.31 (4.54)	185 (115)	2.45 (1.52)	44.8 (5.25)	71.0	46	29.04
"	0.75 (0.47)	7.70 (4.79)	226 (140)	3.40 (2.11)	36.9 (6.38)	70.0	46	29.21
"	0.83 (0.52)	7.92 (4.92)	205 (127)	2.94 (1.83)	40.3 (5.84)	69.0	51	29.13
"	0.90 (0.56)	8.89 (5.53)	208 (129)	2.93 (1.82)	39.4 (5.97)	67.5	55	29.03
no device	0.89 (0.55)	7.97 (4.95)	207 (129)	3.55 (2.21)	39.9 (5.90)	70.0	76	29.08
"	0.93 (0.58)	9.57 (5.95)	207 (129)	2.85 (1.77)	39.4 (5.97)	67.5	48	28.87
Mark II "dry"	0.88 (0.55)	8.31 (5.16)	216 (134)	3.51 (2.18)	38.2 (6.16)	74.0	33	29.05
"	0.88 (0.55)	7.90 (4.91)	215 (134)	3.56 (2.21)	38.5 (6.11)	74.0	31	29.05

changed and the cylinder deposits if affected at all would only be slightly altered in the one cylinder. Third, when the valve was replaced considerable care was taken not to disturb the combustion chamber deposits. It is our conclusion therefore that the tests taken after the valve was replaced are valid representations of the effect of the Mark II after approximately 2,000 miles.

Table 4 contains the average fuel economies and standard deviations of the three configurations tested before and after mileage accumulation for the '75 FTP. Also shown are the percent improvement and t test value* using the no-device configuration before mileage accumulation as the base sample. The final column in this table is the resolution to the t test null hypothesis, i.e., that there is no significant difference between the configuration and the base sample with a confidence level of 90%. A "yes" in this column indicates that there is a significant difference at that confidence level. By this test none of the configurations showed a significant difference from the base sample. While some of the configurations showed mean percent improvements of 2.0 percent, these changes were not sufficiently different from the test-to-test variability to be considered significant.

Table 5 is the same format as Table 6 for the Highway cycle fuel economies. While the configurations showed decreases in fuel economy up to 3.3 percent, none were found to be significantly different from the observed variability.

Table 6 is again the same format for the hydrocarbon, carbon monoxide, and nitrogen oxides emissions of the '75 FTPs. Many of the configurations showed mean percent reductions in the order of 10 percent, and the Mark II after 2000 miles showed a 16.7 percent reduction in nitrogen oxides. Despite the apparently large percentages of reduction, none of these were found to be significantly different from the test-to-test variability.

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* The t tests were calculated using an overall standard deviation calculated by averaging the variances of the six test sets (3 configurations before and 3 after 2000 miles) using the equation:

$$\sigma^2_{av.} = \sum_{i=1}^{6} n_i \sigma_i^2 / \sum_{i=1}^{6} n_i$$

where n_i = sample size of test set i

σ_i^2 = the variance (standard deviation squared) of test i

This involves the reasonable assumption that while the mean value of the test sets may vary, the test-to-test variability within each set is the same for all six sets.

Table 4

'75 FTP Fuel Economy Statistics

Test configuration	Sample size	Mean mpg	Standard dev. mpg	Standard dev. %	Percent improvement*	t*	Significantly different at 90% confidence
Before mileage accumulation							
no device	2	25.3	±0.3	±1.1	-	-	-
Mark II	3	24.9	±0.3	±1.3	-1.6	+1.21	No
Mark II "dry"	2	25.8	±0.1	±0.3	+2.0	-1.38	No
After 2000 miles							
no device	2	25.8	±0.1	±0.3	+2.0	-1.38	No
Mark II	3	25.8	±0.7	±2.6	+2.0	-1.52	No
Mark II "dry"	2	25.9	±0.0	±0.0	+2.4	-1.66	No

* All percent improvement and t tests conducted with no device before mileage accumulation used as the base sample. The t tests were calculated using an overall standard deviation of ±0.36 mpg for the '75 FTP fuel economy.

Table 5

Highway Cycle Fuel Economy Statistics

Test configuration	Sample size	Mean mpg	Standard dev. mpg	Standard dev. %	Percent improvement*	t*	Significantly different at 90% confidence
Before mileage accumulation							
no device	3	39.7	±0.4	±1.0	-	-	-
Mark II	5	38.9	±1.0	±2.7	-2.1	+1.72	No
Mark II "dry"	3	39.2	±0.1	±0.1	-1.3	+0.96	No
After 2000 miles							
no device	2	39.6	±0.4	±0.9	-0.3	+0.17	No
Mark II	3	39.6	±0.6	±1.5	-0.3	+0.19	No
Mark II "dry"	2	38.4	±0.2	±0.6	-3.3	+2.23	No

* All percent improvement and t tests conducted with no device before mileage accumulation used as the base sample. The t tests were calculated using an overall standard deviation of ±0.64 mpg for the Highway Cycle fuel economy.

Table 6

'75 FTP Composite Emissions Statistics

Test configuration	Sample size	Hydrocarbons: Mean g/mi.	Standard dev. g/mi.	Standard dev. %	Percent reduction*	t*	Significantly different at 90% confidence	Carbon Monoxide: Mean g/mi.	Standard dev. g/mi.	Standard dev. %	Percent reduction*	t*	Significantly different at 90% confidence
Before mileage accumulation													
no device	2	1.71	±0.08	±5.0	--	--	--	29.6	±5.4	±18.2	--	--	--
Mark II	3	1.55	±0.11	±7.2	+9.6	+1.69	No	27.4	±3.4	±12.4	+7.4	+0.91	No
Mark II "dry"	2	1.57	±0.13	±8.1	+8.2	+1.35	No	29.0	±0.6	± 2.0	+2.0	+0.23	No
After 2000 miles													
no device	2	1.66	±0.10	±6.0	+2.9	+0.48	No	27.1	±1.3	± 5.0	+8.6	+0.94	No
Mark II	3	1.54	±0.10	±6.3	+9.9	+1.79	No	26.1	±0.1	± 0.4	+11.9	+1.45	No
Mark II "dry"	2	1.54	±0.11	±6.9	+10.2	+1.63	No	25.6	±1.1	± 4.1	+13.3	+1.51	No

Test configuration	Sample size	Nitrogen Oxides: Mean g/mi.	Standard dev. g/mi.	Standard dev. %	Percent reduction*	t*	Significantly different at 90% confidence
Before mileage accumulation							
no device	2	2.08	±0.06	±2.7	--	--	--
Mark II	3	2.07	±0.18	±8.7	+0.5	+0.06	No
Mark II "dry"	2	2.22	±0.19	±8.6	-6.5	-0.77	No
After 2000 miles							
no device	2	1.98	+0.33	±16.4	+4.8	+0.35	No
Mark II	3	1.73	±0.05	±2.7	+16.7	+2.12	No
Mark II "dry"	2	2.22	±0.18	±7.9	-7.0	-0.77	No

* All percent reduction and t tests conducted with no device before mileage accumulation used as a base sample. The t tests were calculated using overall standard deviations of:

±0.10 g/mi. for HC
±2.65 g/mi. for CO
±0.18 g/mi. for NOx

Table 7 gives the levels of change that were necessary to be considered significantly different at 90% confidence with the observed test variability and different sample sizes. This shows that a sample size of 7 is required to be able to detect with 90% confidence a difference equal to the standard deviation. Sample sizes of this order can be obtained in this analysis if all the before mileage accumulation tests are grouped and compared to all the after 2000 miles tests. This grouping should reveal any overall shifts in emissions or fuel economy with mileage accumulation and thus reveal any long term benefit of the Mark II. Table 8 shows the results of this grouping for the emissions over the '75 FTP and for the fuel economies over the '75 FTP and HFET. Under the column titled "Comparative Statistics" are given the percent change in the group means, the t test score and the resolution of the same t test null hypothesis as used in Tables 4, 5, and 6.

The CO and NOx emissions showed reductions of 7% and 8% respectively but just missed being significantly different from test-to-test variability. The '75 FTP fuel economy improvement of 2% was found significantly different. From this there appeared to be a slight but real improvement in the 75 FTP fuel economy after mileage accumulation with the Mark II. There was no corresponding improvement in the HFET fuel economy.

Any fuel economy benefits that would result from the alteration of the combustion chamber deposit, would be expected to be reflected in both the 75 FTP and HFET. Thus it was difficult to envision a long term effect of the Mark II that would tend to improve only the low speed stop-and-go type driving fuel economy.

Table 9 shows the combined city/highway fuel economy of the test vehicle in the different configurations tested. Also shown is the fuel consumed and its cost over a period of one year of average driving, assuming the annual mileage of 10,000 miles and gasoline cost of $.60/gallon. The Mark II after mileage accumulation showed a savings of $2.58 over the no-device configuration before mileage accumulation. The price of the Mark II with Vapor Jet is listed at $47.90. The owner's manual recommends refilling the Mark II with Econo Mix ($1.95 for a 15 oz. can) every 90 days, yielding an annual operating expense of $7.80. Thus, at least for the test vehicle the Mark II does not appear economically justifiable.

Table 7
Percent difference between sample means detectable at 90% confidence as a function of sample size

	Overall Std. dev.%	Percent difference detectable with no. of tests* equal to 2	3	4	5	7	10
'75 FTP Emissions							
HC	±5.8	±17.1	±10.2	±8.0	±6.9	±5.6	±4.5
CO	±9.0	±26.1	±15.6	±12.3	±10.5	±8.5	±6.9
NOx	±8.7	±25.3	±15.1	±11.9	±10.2	±8.2	±6.7
Fuel Economy							
75 FTP	±1.4	±4.2	±2.5	±2.0	±1.7	±1.4	±1.1
HFET	±1.6	±4.7	±2.8	±2.2	+1.9	±1.5	±1.2

* No. of tests is for both samples, each having the same indicated number of individual tests, i.e. the number 5 indicates two samples of 5 tests each for a total of 10 tests.

Table 8

'75 FTP emissions	Before mi. accum. Sample size	Mean g/mi	After 2000 mi. Sample size	Mean g/mi	Comparative Statistics Percent change*	t*	Significantly different at 90% confidence
HC	7	1.60	7	1.57	-1.9	0.56	No
CO	7	28.5	7	26.2	-7.1	1.61	No
NOx	7	2.11	7	1.94	-8.1	1.78	No
Fuel Economy		mpg		mpg			
'75 FTP	7	25.3	7	25.8	+1.9	2.92	Yes
HFET	11	39.2	7	39.3	+0.3	0.32	No

* Before mileage accumulation mean values were used as base sample for percent change and t test. Overall standard deviations used are those given in Tables 4, 5, and 6.

Table 9

Configuration	Composite fuel economy mpg *	Gasoline used per year gallons **	Gasoline cost per year ***
Before mileage accumulation			
no device	30.2	331.1	$198.66
Mark II	29.7	336.7	$202.02
Mark II "dry"	30.4	328.9	$194.34
After 2000 miles			
no device	30.6	326.8	$196.08
Mark II	30.6	326.8	$196.08
Mark II "dry"	30.3	330.0	$198.00

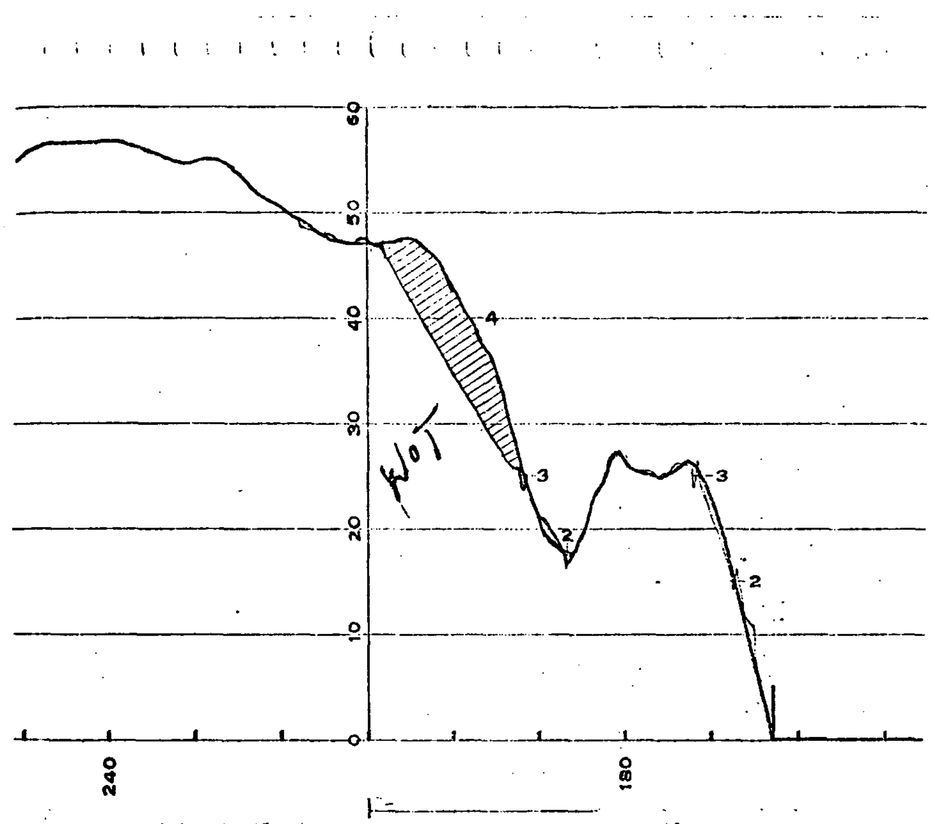
Performance of the vehicle was not specifically examined, but the vehicle was unable to maintain the hard acceleration occurring from 180 to 200 seconds into the transient cycle of the '75 FTP. Figure 6 shows this section of the driving cycle, with the cross hatched area representing the difference between the prescribed speed time trace (upper curve) and the vehicle's actual speed time trace. The "WOT" on the trace was written by the driver indicating that the throttle was wide open. Had any power improvements occurred, the vehicle would have been better able to follow the prescribed trace and the cross hatched area would have been smaller. Since no noticeable changes in this area were produced by any of the configurations tested, it was concluded that no noticeable changes in vehicle performance occurred.

* Composite fuel economy $= \dfrac{1}{\dfrac{.55}{\text{'75 FTP F.E.}} + \dfrac{.45}{\text{Highway F.E.}}}$

** Annual mileage 10,000 miles

*** Gasoline cost of $.60/gallon

Figure 6



Typical speed-time trace for the Vega in the region of 180 to 240 seconds into the '75 FTP. Cross-hatched area added for clarity.

Conclusions

The calculations of the preliminary analysis show that the quantities of water, methanol, and acetone added by the Mark II are considerably smaller than additions reported in the literature that produced measureable changes in octane requirement, power, or fuel economy. The Mark II can be considered as a small auxiliary carburetor, which under favorable conditions delivers a mixture with an air fuel ratio near stoichiometric. If this addition to the total carbureted mixture were ignored, the apparent increase in fuel economy was calculated to be around 0.3 percent on the '75 FTP. If the Mark II were operated "dry" it could increase the overall air fuel ratio by 0.28 at idle. Depending on the original air fuel ratio, this could produce small but measurable changes in emission levels and low speed fuel economy. Possible long term effects of the Mark II were not considered in the preliminary analysis.

The test results show that all configurations tested yielded the same emissions and fuel economy within test-to-test variability. By combining all tests before mileage accumulation and comparing them to all the after-2000 mile tests, a significant 2% increase in '75 FTP fuel economy was observed with mileage accumulation. There was not a corresponding increase in HFET fuel economy. Throughout the testing sequence no improvements in vehicle performance were observed.

Based on the results from the test car, the operating expenses of the Mark II exceeded the savings in fuel by a factor of three. It is the conclusion of the analysis that the purchase price and operating expenses of the Mark II do not appear to be justified by the insignificant changes in emission levels and minor fuel economy improvement produced by the Mark II.

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Appendix I

Preliminary analysis of Mark II Vapor Injector

The purpose of this preliminary analysis is to determine the approximate concentration of the various vapors in the carbureted air fuel mixture, and to compare them to concentrations, reported in the literature, known to produce measurable effects.

Mark II Econo Mix fluid is 65% methanol, 34% acetone and 1% propylene glycol by volume. This is mixed one part to two parts water by volume. As only the vapors of this mixture are used and the vapor pressure of propylene glycol is low (less than 1 mm of Hg at 100°F), we will not include it in our analysis.

Water vapor is normally added to air-fuel mixtures because it is present in the air. The effects of increasing humidity are fairly well known. It lowers the octane requirement of the engine, i.e. it acts as a knock suppressor. Potter et al[7] found that at 70°F a change in relative humidity from 30 to 60 percent decreased the required motor octane number (MON) of the fuel for an automobile engine from 88 to 86. Ingamello, Stone, Gerber and Ungelman[7] found studying eight automobiles that the effects of humidity changes on required octane number was linear with the equation:

$$\Delta \text{ O.N.} = - K \, \Delta H \text{ (grains/lb absolute humidity)}$$

K was observed to vary from 0.04 to 0.09 for the cars tested with an average of 0.045. This is in good agreement with Potter, yielding a 1.4 O.N. decrease versus the 2 from Potter for the 30% change in relative humidity at 70°F.

As a diluent, water vapor also decreases the charge density and indicated thermal efficiency. Slight power improvement is possible with increasing humidity if the engine was previously spark limited and can take advantage of the increased octane number by increasing spark advance and/or increasing charge density (opening the throttle more for a normally aspirated engine).

Nichols, El-Messiri and Newhall[9] investigated the effects of inlet manifold water injection on oxides of nitrogen emissions. They found that at air-fuel ratios near stoichiometry, 30 to 50 percent reduction of nitric oxide emissions were observed with a water to fuel weight ratio (W/F) of 0.50. The effects of water injection on percent reduction of NOx appeared linear in the range of W/F = 0 - 0.5. The effectiveness of water in this regard was attributed primarily to its high latent heat of vaporization resulting in lower peak combustion temperatures.

Obert[10] investigated injections of liquid water and water-alcohol mixtures into the intake manifold as a means of knock suppression. While effective, it required large amounts of water, around 50% of the fuel volume. This technique has been used for airplane engines during take-off. Much of the effectiveness of this method has been attributed by Obert to the high latent heat of vaporization of the liquids.

Methanol has been widely investigated as a possible fuel blending component and alternate fuel. Ingamells and Lindquist[11] found, using different unleaded gasolines, that the addition of 5% by volume methanol increased the MON by 0.1 to 1.5 octane number (ON) while the addition of 10% methanol increased the MON by 1.6 to 2.5 ON. They also reported that on a miles per gallon basis the addition of 10% methanol produced an average 3.2% fuel economy loss for a six car fleet in commuter type driving. Wigg and Lunt[12] reported the effects of the addition of 15% methanol by volume to gasoline on the exhaust emissions of cars operated over the '75 FTP. For a 1973 car the methanol addition resulted in a 36% increase in HC, a 50% decrease in CO, and a 24% decrease in NOx. These effects however were attributed to 1) the enleanment effect of using the alcohol blends in carburetors designed for gasoline (The addition of 15% methanol increased the equivalence ratio by about 0.1 unit.), and 2) the relatively higher latent heat of vaporization of methanol resulting in a cooler inlet charge and lower peak flame temperatures. In Powell's[11] review of racing motor-fuel blends he estimates a 20% gain in power for high compression ratio engines using methanol instead of regular gasoline. This was attributed to methanol's 1) ability to burn richer of stoichiometric than gasoline, 2) higher octane number and 3) higher heat of vaporization producing cooler, denser inlet charges. This power increase also entailed a specific fuel consumption of methanol being about three times that of gasoline.

The use of acetone in fuels has not been considered very much because it and other ketones promote the formation of gum. For this reason, production gasolines generally limit naturally occurring ketones to .005 weight percent.[12] Powell reported that acetone was sometimes used in racing fuels in concentrations of 5% or less. It was used with methanol blends as a blend stabilizer and water tolerance booster because of its high solvent powers. Gumming and other fuel system problems associated with acetone and methanol are prevented by draining and flushing of the system after each race.

Turning now to the Mark II we can reasonably approximate the concentrations of water, methanol, and acetone contributed by the device to the induction mixture. First the operating variables of the device were measured. With the aerator valve on the Mark II reservoir adjusted according to the manufacturer's instructions, the air flow into the valve was measured with a wet test meter. The air flow was 1.4 cubic feet per hour with the engine idling and at steady state 50 mph cruise. At wide open thottle the flow was less than .02 cubic feet per hour. The maximum flow rate measured, 2.6 cubic feet per hour, was with the valve wide open (an improper setting according to the instructions). The temperature of the reservoir fluid was measured throughout a '75 FTP and Highway test with the reservoir installed in the car but not connected to the vacuum source. As there was no air bubbling through the fluid the evaporative heat losses associated with it were not present. The initial temperature was 80°F and the final temperature after 60 minutes was 98°F and still rising slowly. The vacuum in the bottle with the air bubbling rate properly adjusted was 10 inches of mercury. For convenience we will use an air flow of 1.4 cubic feet per hour, reservoir temperature of 100°F and an absolute pressure in the bottle of 20 in. Hg in our calculations below.

Calculation of weight of air, water, methanol and acetone delivered per hour by the Mark II:

Assumptions

1. Air entering bottle is at 80°F and at 50% relative humidity.

2. Fluid mixture obeys Raoult's Law, i.e. each component's equilibrium vapor pressure above the liquid is equal to the vapor pressure of the pure component's equilibrium vapor pressure at that temperature times the mole fraction of that component in the liquid mixture.

3. The vapor-liquid concentrations are in equilibrium after bubbling.

Given the Econo Mix composition of 65% methanol, 34% acetone and 1% propylene glycol, mixed with 2 parts water; the resulting mixture per litre is:

water	667 ml
methanol	217 ml
acetone	113 ml
propylene glycol	3 ml
	1000 ml

Component	Density g/litre	Molec. Wt.	Moles/litre pure component	Mole fraction in mixture
water	1.00	18.0	55.6	.842
methanol	0.79	32.0	24.7	.122
acetone	0.79	58.1	13.6	.035
propylene glycol	1.04	76.1	13.7	.001

Absolute pressure in bottle is 20 in. Hg or 510 mm Hg.

Component	Mole fraction in liquid	Vapor pressure of pure component at 100°F in mm Hg	Partial pressure above mixture	Mole fraction in air vapor mixture
water	.842	49	43.3	.085
methanol	.122	230	28.1	.055
acetone	.035	380	13.5	.026
propylene glycol	.001	1	0.0	.000
air	---	---	425.	.834
Total			510	1.000

Below the composition of one mole of air-vapor mixture (22.4 ℓ at standard conditions of $0^{o}C$ and 1 atm.) and the weight and volumes of these components delivered per hour by the Mark II are shown.

Component	Weight per 1 mole of mixture in grams*	Weight delivered in one hour in grams**	Liquid volume delivered in one hour in ml.
water	1.53	3.28	3.28
methanol	1.76	3.77	4.77
acetone	1.51	3.23	4.09
propylene glycol	0.00	.00	.00
air	24.0	51.4	---

* Molecular weight x mole fraction in air-vapor mixture

** Total volume of vapor mixture delivered to the engine by the Mark II at STP is:

$$(1.4 \text{ cu. ft./hr.}) \left(\frac{510 \text{ mm Hg}}{425 \text{ mm Hg}} \right) = 1.7 \text{ cu. ft./hr. or } 48 \text{ ℓ/hr.}$$

Calculating the fuel consumed by the test vehicle and the vapor components delivered by the Mark II during the '75 FTP, Highway test and idle:

Cycle	Driving Time hours	Distance miles	Vega F.E.	Gasoline consumed Gallons	Gasoline consumed ml.
'75 FTP	.521	11.1	25.7	.432	1635
Highway	.21	10.2	39.3	.260	982
Idle	1.0	0.0	--	.4+	1500

\+ Estimated from the following idle fuel consumption data from reference 13. '75 Ford Pinto - .426 gal./hr. '75 VW Rabbit - .388 gal./hr.

Component	'75 FTP Volume ml.	'75 FTP Vol.%	Highway Volume ml.	Highway Vol.%	Idle Volume ml.	Idle Vol.%
water	1.71	0.10	0.69	0.07	3.28	0.22
methanol	2.49	0.15	1.00	0.10	4.77	0.32
acetone	2.13	0.13	0.86	0.09	4.09	0.27
gasoline	1635.	99.63	982.	99.70	1500.	99.20
Total	1641.		985.		1512.	

Thus we see that considering the vapor components contributed by the Mark II as part of the fuel, they represent a very small fraction: only 0.30% on the Highway test, 0.37% on the '75 FTP and 0.80% at idle. This checks well with the observed consumption of 550 ml of reservoir fluid during the accumulation of 1600 miles. With a composite fuel economy of 30.4 mpg, 52 gallons or 200 litres of gasoline were used yielding a 0.28% by volume addition of the reservoir fluid.

Water addition due to the Mark II amounted to at most 0.22% and of that, slightly over 50% was the original humidity of the air entering the Mark II. Assuming an overall stoichiometric air fuel ratio, this amounts to a 1.4* grains of water addition per pound of incoming air. This is equivalent to a humidity change of a little less than one relative humidity point at 80°F. Using Ingamells et al[7] equation for the effect of humidity on octane requirement we can expect a decrease of 0.06 O.N. due to the water contributed by the Mark II. This small change in O.N. is not measurable. Using the linear relationship[8] of water addition to percent reduction of NOx observed by Nichols et al[9], we would expect a 0.2 to 0.3 percent reduction in NOx emissions due to the water additions of the Mark II if this water were in a liquid state when it entered the intake manifold. Since the Mark II adds only water vapor the benefits of the high latent heat of vaporization are lost. Thus the actual effect would be smaller than the 0.2 to 0.3 percent reduction above, which is already way below our test-to-test variability. Most important of all however is the fact that normal day-to-day weather variations produce humidity changes that dwarf those produced by the Mark II.

The maximum methanol addition of 0.32 volume percent is an order of magnitude smaller than reported additions of 5% that produced a .1 to 1.5 octane number change. Assuming that the effects of methanol addition to gasoline are linear with the percentage of volume addition, we can estimate the emissions changes over the '75 FTP from the Wigg and Lunt[12] data. That is a 15% by volume addition of methanol to gasoline resulted in a 36% increase in HC, a 50% decrease in CO, and a 24% decrease in NOx. Thus we might expect a 0.8% increase in HC, a 1.1% decrease in CO, and a 0.5% decrease in NOx. Again with the Mark II the effect of the high latent heat of vaporization of methanol is lost so the effect on NOx would be less. These small changes are not measurable on the '75 FTP because of the test-to-test variability. Methanol additions of 0.25% are routinely added to production winter gasolines by some oil companies[14] to prevent ice crystal formation in the fuel. This small addition is not known to have any measurable effect on any engine variable.

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* $.0022 \text{ vol. fraction } H_2O \times \frac{1.00 \text{ density } H_2O}{.739 \text{ density of gasoline}} \times \frac{\text{lb. gasoline}}{15 \text{ lb. air}} \times$ 7000 grains/lb. = 1.4 grains H_2O/lb. air.

As mentioned earlier acetone is avoided in production gasolines. It has been used in methanol blend racing fuels, in concentrations up to 5%, as a blend stabilizer, not for any known benefits as an octane or power booster. The maximum concentration of acetone contributed by the Mark II was 0.27%. It is unlikely that this small a concentration would produce any measurable effects.

As methanol and acetone are combustible, the Mark II can be considered as an auxiliary carburetor. Below is a calculation of its equivalence ratio. (Equivalence ratio is the observed air-to-fuel ratio by weight divided by the stoichiometrically correct air-fuel ratio for that fuel. A rich mixture will have an equivalence ratio less than 1.0 and a lean mixture will have one greater than 1.0)

Component	Mole fraction in air vapor mixture	moles of O_2 per mole of component for complete oxidation	Mole fraction of O_2 require
methanol	.055	1.5	.083
acetone	.026	4.0	.104
air	.834	---	---
O_2 .21 x .834 =	.175	---	---
		Total	.187

So equivalence ratio is $\frac{.175}{.187}$ = .935 or slightly rich.

So when the Mark II reservoir fluid is fresh and at 100°F the air-vapor mixture is rich. When the reservoir is cooler, the mixture will be leaner. Also with mileage accumulation, as the conentrations of methanol and acetone are depleted, the mixture will become leaner. Since the methanol and acetone represent at most only 0.59% of the fuel their effect on the overall air-fuel ratio is minimal. If the Mark II were operated without fluid ("dry"), the air entering would lean the carbureted mixture. At idle an original A/F of 15.0:1 would go up to:

$$\frac{6.0 \text{ lb. air/hr.} + (1.4 \text{ cu. ft air/hr.} \times .079 \text{ lb/cu. ft air})}{.4 \text{ lb. fuel/hr.}} = 15.28$$

or a 1.8% increase. The effects of air-fuel ratio changes on fuel economy and emissions are well documented; and while this is the maximum increase expected, it is sufficient at certain air fuel ratios to produce small but measurable changes in emissions and low speed fuel economy. This would be operating the Mark II strictly as air bleed, and similar results could be obtained by leaning the normal idle mixture adjustment.

Since the fuel economies of this report are calculated by the carbon balance method the carbon added by the Mark II is counted. In the calculation, a carbon-to-hydrogen ratio and a density typical of gasoline are used. This creates an error if a gasoline is used that is not typical.

For the '75 FTP we can determine the error in the calculated fuel economy which resulted when 0.28% of the fuel was not typical gasoline but was acetone and methanol.

Fuel	1 Density grams/gallon	2 (Grams of Carbon) (Gram molec. wt. of fuel)	1 x 2	3 Volume fraction	1 x 2 x 3
Gasoline	2798	.866	2423	.9972	2416
Methanol	2990	.375	1120	.0015	1.7
Acetone	2990	.620	1850	.0013	2.4
			Total		2420

$$\text{Percent error} = (1 - \frac{2420}{2423}) \times 100 = 0.12\%$$

That is the calculated fuel economy is 0.12% higher than actuality. At 25.0 mpg this error amounts to .030 mpg, or beyond the significance to which we report fuel economy.

If the methanol and acetone were not considered as fuel during the '75 FTP, the calculated fuel economy would be $(1 - \frac{2416}{2423}) \times 100 = 0.29\%$ higher than actuality.

For 25.0 mpg this amounts to .072 mpg. This then is the magnitude of change we would expect by ignoring the fuel content of the Mark II vapors, measuring only the volume of gasoline consumed and dividing it into the miles traveled, as the typical motorist might do. Even though this is technically incorrect it still represents a very minor change in fuel economy.

Not discussed above is the possible long term effects of the device such as altered combustion chamber deposit quality or quantity. In evaluating aftermarket devices, TAEB is not particularly concerned with these changes unless they affect the emissions, fuel economy, or performance of the vehicle.

Appendix II

'75 FTP Individual Bag Results
Mass emission, grams per mile
Fuel economy, miles per gallon

	Bag 1 Cold Transient					Bag 2 Hot Stabilized					Bag 3 Hot Transient							
Test Number	HC	CO	CO_2	NOx	Fuel Economy	HC	CO	CO_2	NOx	Fuel Economy	HC	CO	CO_2	NOx	Fuel Economy	Temp. °F	Rel. Hum. %	Baro. P " Hg
19-8205	2.41	53.8	295	2.26	22.9	1.45	25.6	312	1.85	24.9	1.91	33.0	262	2.53	27.8	74.5	46	29.02
19-8224	2.69	41.9	316	2.35	22.8	1.27	20.1	312	1.69	25.5	1.58	24.6	272	2.48	28.1	73.0	46	29.35
19-8277	2.42	52.9	293	2.18	23.1	1.30	19.9	309	1.81	25.8	1.79	30.0	260	2.54	28.3	71.5	49	28.75
19-8324	2.36	57.3	307	2.49	21.9	1.16	17.3	304	2.02	26.5	1.44	28.6	272	2.87	27.6	74.5	41	29.03
16-8721	2.34	47.3	303	2.44	23.0	1.02	16.6	336	2.07	24.3	1.54	24.9	282	1.06	27.2	75.0	34	29.48
15-8740	2.90	48.2	299	2.25	23.1	1.10	17.5	324	1.94	25.0	1.41	24.4	275	2.71	27.9	65.5	45	29.34
15-8810	2.41	50.0	292	2.30	23.4	1.27	22.1	322	1.86	24.6	1.80	34.9	281	2.57	26.0	71.5	48	28.83
15-9009	2.68	45.9	298	2.22	23.4	1.31	23.7	312	1.61	25.1	1.70	29.6	265	2.33	28.0	74.0	38	28.90
15-9019	2.42	44.1	302	2.31	23.4	1.35	23.3	332	1.85	23.8	1.59	26.5	270	2.66	28.0	72.0	44	29.09
15-9047	2.98	47.4	307	2.29	22.7	1.39	23.5	332	1.72	23.8	1.62	27.7	275	2.49	27.4	72.0	40	29.01
15-9064	2.50	46.5	301	2.24	23.2	1.43	23.4	329	1.75	23.9	1.52	26.9	266	2.41	28.3	74.0	38	28.84
16-9086	3.31	48.4	298	2.17	23.1	1.47	24.0	326	1.63	24.1	1.58	26.6	275	2.53	27.6	74.0	40	29.17
15-9162	4.06	56.0	302	2.13	22.0	1.59	24.8	334	1.77	23.5	1.79	28.8	276	2.43	27.1	74.0	41	28.98
16-9179	3.77	51.1	303	2.24	22.5	1.65	23.7	333	1.72	23.6	1.82	28.2	275	2.47	27.3	74.0	46	28.99
16-9192	4.04	53.2	291	2.14	22.9	1.67	22.2	309	1.60	25.4	1.69	24.6	261	2.42	29.1	70.0	46	29.13
16-9219	3.91	55.2	304	2.18	22.0	1.69	21.7	330	1.77	24.0	1.76	28.2	280	2.39	26.9	73.0	40	28.98
16-9237	3.18	48.4	299	2.13	23.1	1.79	19.4	328	1.71	24.4	1.88	28.4	270	2.34	27.6	72.8	45	28.70
15-9427	3.15	53.9	308	2.14	22.0	2.06	23.7	330	1.78	23.7	1.94	28.8	274	2.51	27.2	72.5	40	28.73
15-647	3.41	51.9	300	2.16	22.6	2.07	24.0	332	1.60	23.6	2.16	29.5	276	2.45	26.9	73.0	44	28.96
15-719	3.73	52.9	311	2.37	21.9	2.46	24.8	319	1.62	24.2	2.30	29.3	293	2.76	25.6	74.0	48	29.18
15-720	3.48	54.1	311	2.37	21.8	2.30	22.0	341	1.71	23.2	2.24	28.2	285	2.67	26.4	73.0	44	29.25
16-1280	2.59	50.8	318	2.00	21.9	0.99	18.1	356	1.74	22.9	1.54	28.2	293	2.36	25.9	77.0	33	29.12
76-1988	2.76	47.2	290	2.03	23.8	1.11	18.0	318	1.51	25.4	1.57	25.3	279	2.03	27.4	71.0	49	29.06
76-1310	2.13	41.3	258	1.52	26.9	0.46	16.9	324	1.42	25.2	0.70	24.6	231	1.68	32.6	72.0	44	29.03
76-2454	2.60	55.7	281	1.71	23.6	0.95	15.5	311	1.48	26.2	1.45	23.4	255	2.02	29.9	72.5	46	29.13
76-2552	2.89	51.4	291	1.74	23.3	1.12	16.2	331	1.65	24.6	1.59	26.4	267	1.99	28.3	71.5	46	29.03
76-2629	2.54	48.6	284	2.36	24.1	1.20	18.0	314	1.94	25.7	1.60	24.6	277	2.59	27.6	71.0	76	29.08
76-2641	3.15	54.8	295	1.85	22.7	1.21	19.1	309	1.49	25.9	1.64	24.8	261	2.15	29.1	70.5	45	28.87
76-3465	2.41	50.1	289	2.19	23.6	1.22	17.5	318	1.95	25.4	1.74	23.6	257	2.33	29.3	80.0	44	29.03
76-3458	2.08	44.7	294	2.40	23.9	1.12	17.1	321	2.25	25.3	1.64	24.9	260	2.50	29.2	77.0	27	29.09

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