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EXPERIMENTAL RESULTS USING METHANOL AND METHANOL/GASOLINE BLENDS AS AUTOMOTIVE ENGINE FUEL

By

J. R. Allsup

Date Published—January 1977

Bartlesville Energy Research Center
Energy Research and Development Administration
Bartlesville, Oklahoma

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EXPERIMENTAL RESULTS USING METHANOL AND METHANOL/ GASOLINE BLENDS AS AUTOMOTIVE ENGINE FUEL

by

J. R. Allsup[1]

ABSTRACT

An experimental program was conducted by the Energy Research and Development Administration's Bartlesville (Okla.) Energy Research Center to determine the emission and fuel-economy characteristics of methanol and methanol/gasoline blends as automotive fuel.

Comparative emission and fuel energy economy data were generated using 1975 model vehicles adjusted for gasoline fuel and using gasoline and gasoline blended with 5 and 10 pct methanol; tests were made at temperatures of 20°, 75°, and 100° F on a chassis dynamometer in a climate-controlled test chamber. Results suggest that emissions and fuel energy economy are generally affected to the extent that methanol addition affects air-fuel stoichiometry, fuel heat content, and fuel vapor pressure. The term "fuel energy economy" is used to denote calculations on the basis of fuel energy content in lieu of fuel quantity.

Vehicle emissions and fuel economy were essentially unchanged during approximately 7,500 miles of road testing; no engine or fuel system component failures were encountered during that testing.

Road octane measurements were made for the fuels containing 5, 10, and 15 pct methanol in base gasolines of 84, 87, and 91 research octane quality. Results show significantly better octane improvement in blending methanol with the lower octane fuels as compared with the improvement in blending with the higher octane fuels.

Steady-state engine emission and fuel energy economy data were generated using a late model automotive engine fueled with 5, 10, 15, and 100 pct methanol/gasoline blend. Test variables and engine parametric adjustments included engine speed, exhaust gas recirculation rate, air-fuel ratio, ignition timing, and compression ratio. Results suggest that operation with pure methanol may allow use of high-compression engines to realize improved fuel energy economy with relatively low oxides of nitrogen emission.

[1]Project leader.

INTRODUCTION

Alcohol has been promoted as a motor fuel for almost 70 years. However, significant utilization of alcohol in this use has not developed due to the availability of cheaper petroleum fuels. Recent concern about both environmental problems and our eventual shortage of conventional petroleum-based fuels coupled with the potential for obtaining methanol from coal or various types of "waste" products has again spurred interest in methanol as a motor fuel. Moreover, should petroleum availability be curtailed and supplemental liquid fuel from nonpetroleum sources be required on short notice, the only option for that liquid fuel would be methanol. This appears to be the case because although a background of engineering experience exists that will permit design and construction of coal/gasification/methanol plants using modern technology, no comparable experience background exists in either coal- or shale-conversion technology. Ultimately, other conversion liquids may enter commerce, but presently, given the requirement for immediate production of synthetic liquids for transport use, methanol is the only choice. In connection with these interests in fuel options, the Bartlesville Energy Research Center, Bartlesville, Okla., (first as a component of the U.S. Department of Interior and later as a component of the Energy Research and Development Administration) has conducted tests to determine the feasibility of using methanol as an automotive fuel--used either as nominally pure methanol or used as a fuel component in methanol/gasoline blends. This publication describes experimental testing and results from vehicles using methanol and methanol/gasoline blends. A companion study involving the physical properties of the methanol/gasoline mixtures was conducted concurrently and will be made available as a Report of Investigations entitled "Physical Properties of Gasoline/Methanol Mixtures" by B. H. Eccleston and F. W. Cox. The work was done in part in cooperation with the Environmental Protection Agency.

The experimental work was done with a 10-vehicle fleet using as test fuels a gasoline and that gasoline in blend with 5 and 10 vol-pct methanol. (The percentage methanol is calculated on the basis of original volumes of unmixed components.) The influence of ambient temperature variation was determined for each vehicle of the fleet in tests with the vehicles operated on a chassis dynamometer at controlled ambient test temperatures of 20°, 75°, and 100° F. Work also was done to determine long-term effects, if any, from sustained use of gasoline blends; this segment of the test program involved five of the test vehicles operated for 5,000 to 7,500 miles using 10 pct methanol in gasoline. The vehicles were repetitively driven over a controlled test route during both summer and winter seasonal periods.

The effects of variations in--or changes to--engine parametric adjustment were studied using methanol and methanol/gasoline blends in an engine operated on a test stand. This work was done using both pure methanol and methanol as 5, 10, and 15 pct components of gasoline/methanol fuel.

Prior to vehicle and engine testing, analytical procedures were developed to measure accurately methanol in the presence of other gasoline combustion products.

VEHICLE FLEET TESTS

A fleet of ten 1974 and 1975 vehicles was used in the test program; they are described in table 1. (Vehicle K was not used in the emissions study but was included in the mileage accumulation study; it is described here for convenient reference.) The 1975 vehicles were purchased new, and prior to use in the experimental program were "broken in" using unleaded fuels in 2,500 miles operation in city and moderately severe highway driving. When brought into this study, the two 1974 model vehicles had been driven about 10,000 miles. To ensure against unusual "deposit effects" from this prior usage, the engine heads were removed, and deposits were cleaned from exposed combustion chamber surfaces.

TABLE 1. - Test vehicles operated on methanol/gasoline fuel blends

Vehicle designation	Year and make	Engine size, CID	Transmission	Carburetor
A......	1974 Chevelle	350	Automatic	2 bbl
B......	1974 Ford Torino	351	"	"
C......	1975 Maverick (non catalyst)	250	"	1 bbl
D......	1975 Vega	140	"	1 bbl
E......	1975 Chevelle	350	"	2 bbl
F......	1975 Granada (non catalyst)	351	"	"
G......	1975 Dodge Dart (non catalyst)	318	"	2 bbl
H......	1975 Impala	454	"	4 bbl
I......	1975 Monza	262	"	2 bbl
J......	1975 Plymouth (non catalyst)	318	"	"
K......	1972 Buick	350	"	4 bbl

The test vehicles were initially checked to ensure that all engine adjustments were within manufacturers' specifications. No attempt was made to optimize the engine systems for best utilization of the methanol. For the vehicle fleet tests, the methanol concentration was limited to 10 pct since operation at much greater than 10 pct methanol requires some carburetor modification to ensure adequate drivability.

Analytical Equipment

The vehicles were tested using the 1975 Federal Emissions Test Procedure (FTP) including the Environmental Protection Agency (EPA) highway fuel economy test. The exhaust was collected in Tedlar film bags and analyzed for carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), total aldehydes, total hydrocarbons (HC), HC distribution, and total methanol (MeOH) emissions.

Carbon monoxide and CO_2 were determined using nondispersive infrared (NDIR), NO_x was determined using chemiluminescence, and aldehydes by 3-methyl-2-benzothiazolone hydrozone hydrochloride (MBTH). Compositional data needed to calculate HC distribution were obtained by gas chromatography. Unburned hydrocarbon was determined using a hot-flame ionization detector (FID) for which the sampling line and FID hot sections were maintained at about 375° F. Unburned methanol was determined by gas chromatography. Because information on methodology for measurement of unburned MeOH is not readily available, details of the procedure may be of particular interest; this information is included in a following section.

The response of the FID unit to unburned methanol was experimentally determined to be about 0.75 compared to 1.00 for gasoline exhaust. To correct for the reduced methanol response, the reported HC values were calculated as the sum of the unburned HC in the exhaust (as determined by FID) plus 25 pct of the unburned methanol as determined by gas chromatography. For practical purposes, however, the contribution of unburned methanol to the total exhaust HC was found generally to be negligible.

Fuel economy was calculated using experimental data on exhaust mass flow and exhaust gas composition.(1)[2]

Method of Analysis for Unburned Methanol

Because there is no standard procedure for measuring methanol in the 1 to 200 ppm range in the presence of other gasoline exhaust products, it was necessary to develop an adequate procedure for isolation and measurement of methanol in the presence of interfering hydrocarbons. The procedure that was developed utilized sampling by the constant volume sampling (CVS) method and determination of the methanol content by gas chromatography. The gas chromatograph (figure 1) was equipped for programed temperature control with sub-ambient temperature capability; detection was by flame ionization. Two stainless steel columns, 6 feet in length by 1/8 inch outside diameter and 0.1 inch inside diameter were packed with Carbopack "A" coated with 0.4 pct Carbowax 1500 and operated in series. After the elution of methanol, the first column was backflushed in order to reduce analysis time.

A large sample volume (25 cm^3) was used. The sample loop of 1/4 inch stainless steel tubing and an associated sample valve were maintained at 70° C. Primarily as a means to achieve repeatability free of operator error, the system was automated to initiate and control the temperature program and to control the solenoid valves used for sample and back-flush operations.

Chromatograph operation consisted of cooling the columns initially to 0° C and programing rapidly (32° C/min) to a final temperature of 90° C.

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[2]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

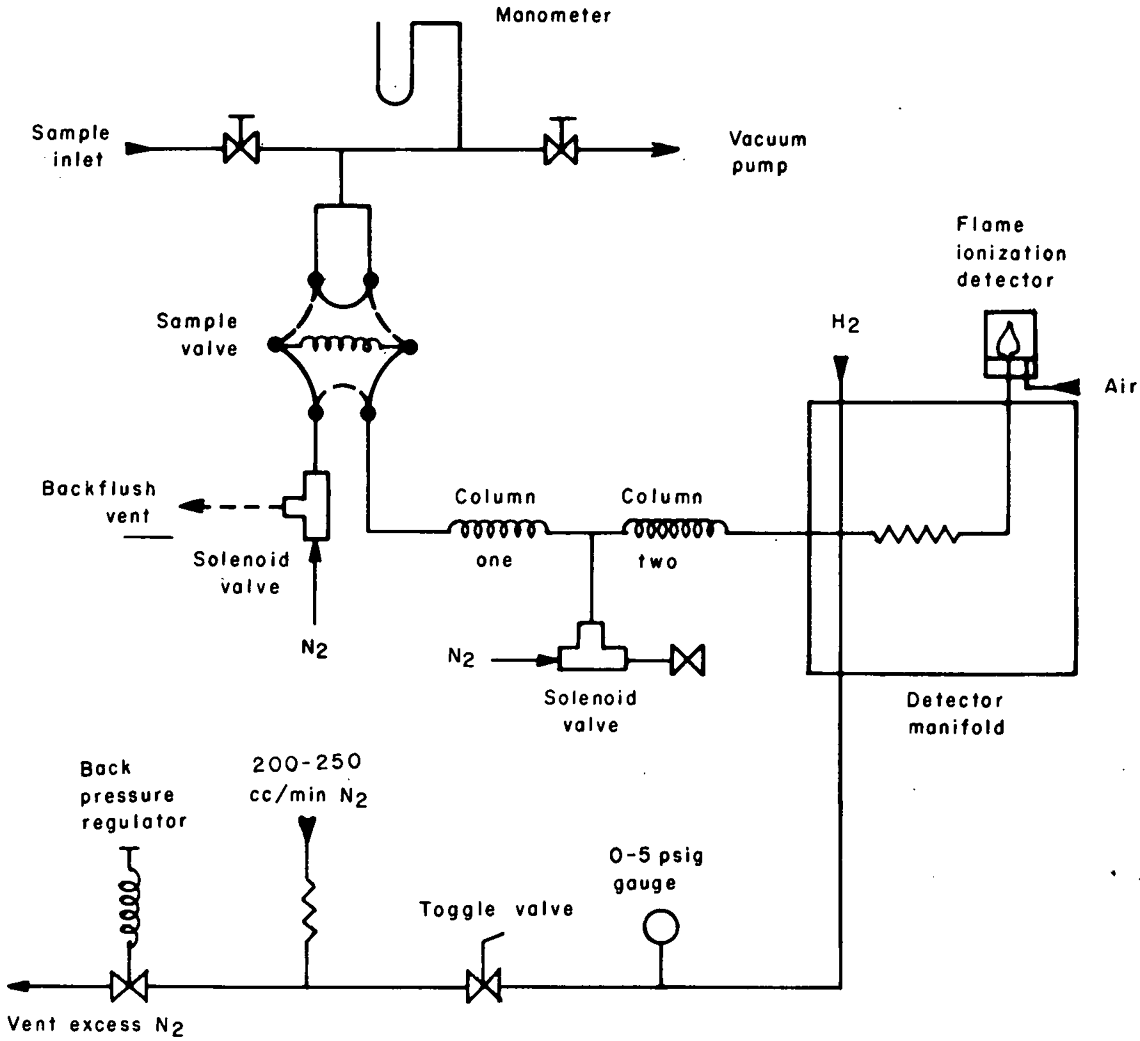

FIGURE 1. - Chromatographic System for Methanol Analysis.

A helium carrier flow of 33 cm^3/min at room temperature was used. Measurement was complicated by a baseline shift that immediately preceded the methanol peak--caused by elution of water which disturbed flame conditions. This baseline shift was minimized by adjusting the backpressure regulator for maximum nitrogen makeup without extinguishing the hydrogen flame. Methanol elution time was 3.5 minutes and occurred between C_3 and C_4 hydrocarbon peaks (figure 2). The total cycle including backflush and cooldown operations, required approximately 12 minutes.

Fuels

Two unleaded gasolines (Indolene and a commercial fuel) were used as base fuels for all tests made with five of the vehicles (A, B, C, D, and E). The remaining five vehicles (F through J) were tested only with the commercial

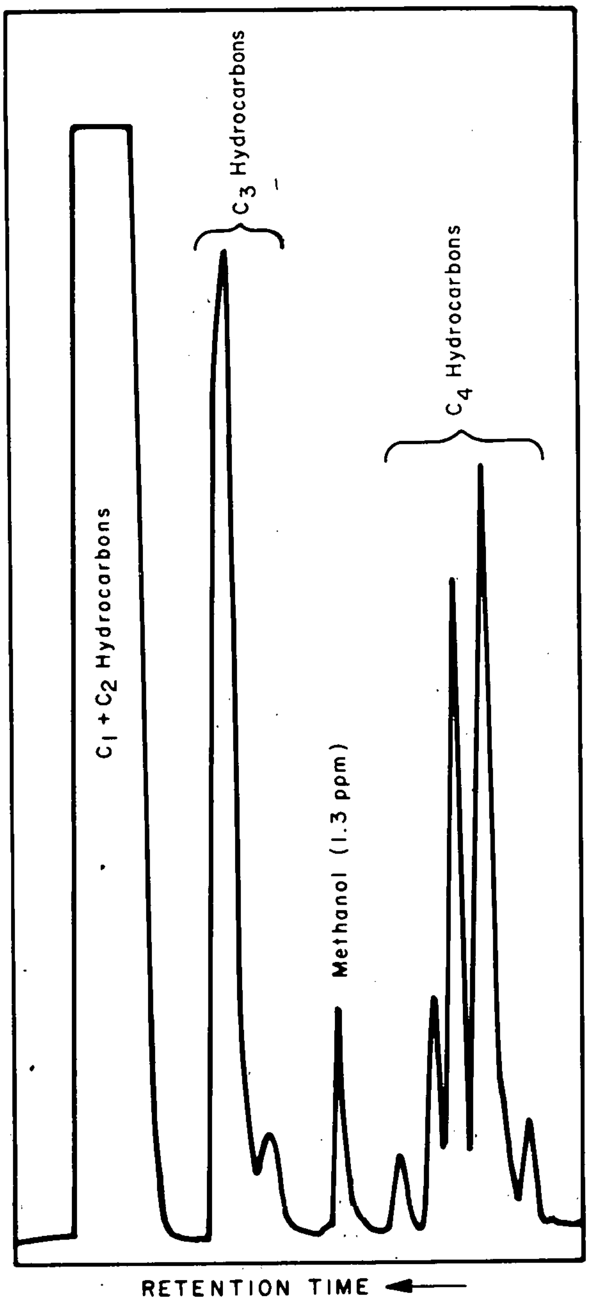

FIGURE 2. - Chromatogram from Methanol Analysis.

base fuel. Test data were obtained with each base fuel used alone and in blend with 5 and 10 pct methanol. Fuel-inspection data are shown in table 2. Fuel energy content for the base fuels (prior to methanol addition) was calculated using information on fuel gravity, distillation, and aromatic content (4). Energy contents of the methanol/gasoline blends were calculated by combining the heating values for appropriate proportionate volumes of alcohol and the base fuel.

EXPERIMENTAL RESULTS

Hydrocarbon Emissions

The emissions data (tables 3 and 4) show that for both base fuels used at normal ambient temperature average HC emissions were increased by addition of methanol and were further increased (up to 30 pct) at the higher temperature. At the 20° F temperature, average HC emissions decreased with addition of methanol to the Indolene base fuel (8.3 lb Reid vapor pressure) but remained essentially unaffected with addition of methanol to the 7.2 lb Reid vapor pressure (RVP) commercial base fuel. These results suggest that the change in HC emissions associated with methanol addition to the Indolene may have been related either to the effect of methanol in leaning the air-fuel ratio (A/F) or to its effect in increasing fuel vapor pressure. (The stoichiometric A/F requirement for clear fuel was 14.7 compared to 14.2 for 5 pct methanol and 13.8 for 10 pct methanol.) It may therefore follow that leaning the A/F in late-model vehicles could be expected to lower HC emissions during cold operation in which the automatic choke is on longer. In like manner, however, hydrocarbon could be increased at normal operating temperature as a result of extending the enleanment of lean-design engines

TABLE 2. - Properties of methanol/gasoline test fuels

	Indolene base fuel			Commercial base fuel		
	Clear	5 pct MeOH	10 pct MeOH	Clear	5 pct MeOH	10 pct MeOH
Reid vapor pressure, psi.	8.3	10.9	11.1	7.2	9.5	9.7
API gravity..............	60.0	59.2	58.9	63.7	62.9	62.1
Research octane No.......	91.6	93.8	96.1	88.0	90.3	93.2
Motor octane No..........	83.9	85.0	85.7	82.4	84.7	85.1
Distillation, °F:						
IBP..................	104	94	96	103	108	109
10 pct evaporated....	134	110	116	140	116	118
30 pct evaporated....	176	160	128	176	164	128
50 pct evaporated....	216	214	206	207	202	198
70 pct evaporated....	252	250	247	235	230	229
90 pct evaporated....	316	316	313	286	284	284
EP...................	383	388	380	383	367	366
FIA, vol pct						
Olefin...............	5	NAP*	NAP	6	NAP	NAP
Aromatics............	26	NAP	NAP	23	NAP	NAP
Phase separation temperature, °F:						
with 200 ppm H_2O.....	NAP	-5	19	NAP	7	24
with 400 ppm H_2O.....	NAP	20	29	NAP	31	34
Energy content, 10^6 btu/gal...........	1.154	1.125	1.095	1.127	1.099	1.071

*NAP = Not applicable

TABLE 3. - Exhaust emissions and fuel rate--vehicles A, B, C, D, E

	Ambient temperature, °F								
	20			75			100		
	Base fuel	5% MeOH	10% MeOH	Base fuel	5% MeOH	10% MeOH	Base fuel	5% MeOH	10% MeOH
	BASE FUEL -- INDOLENE								
Emissions, g/mile:									
CO	48.8	39.1	35.0	17.7	14.2	10.9	25.8	44.0	34.2
HC	2.7	2.6	2.3	1.4	1.6	1.8	1.6	2.0	2.1
NO_x	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.6	1.7
Aldehydes	.09	.11	.13	.10	.12	.13	.09	.10	.09
Methanol	.01	.08	.13	.01	.08	.15	.02	.10	.17
Fuel economy, mi/10^5 btu:									
Emission cycle	8.7	8.6	8.7	10.0	9.8	9.7	10.2	9.6	9.8
Highway cycle	15.4	15.4	15.1	15.9	15.9	15.6	16.4	15.8	15.9
	BASE FUEL -- COMMERCIAL GASOLINE								
Emissions, g/mile:									
CO	48.2	42.3	32.1	18.7	13.2	9.6	19.7	28.3	19.6
HC	2.5	2.5	2.6	1.3	1.6	1.7	1.6	2.1	2.3
NO_x	1.9	1.9	2.0	1.8	1.8	1.7	1.7	1.6	1.7
Aldehydes	.10	.11	.16	.10	.10	.12	.10	.11	.13
Methanol	.02	.08	.14	.02	.08	.15	.02	.10	.17
Fuel economy, mi/10^5 btu:									
Emission cycle	9.5	9.0	8.7	10.1	9.8	9.6	10.3	10.0	9.8
Highway cycle	16.8	15.9	15.2	15.9	15.2	14.9	16.5	16.3	15.8

TABLE 4. - Exhaust emissions and fuel rate--vehicles A through J--commercial gasoline base fuel/methanol blends

	Ambient temperature, °F								
	20			75			100		
	Clear fuel	5% MeOH	10% MeOH	Clear fuel	5% MeOH	10% MeOH	Clear fuel	5% MeOH	10% MeOH
Emissions, g/mile:									
CO	40.3	35.7	29.2	13.5	10.1	8.2	13.2	18.3	13.2
HC	2.5	2.6	2.8	1.1	1.3	1.5	1.2	1.6	1.8
NO_x	1.9	2.1	2.0	2.1	2.0	1.9	2.0	1.8	1.8
Aldehydes	.11	.13	.16	.10	.11	.12	.09	.10	.12
Methanol	.01	.08	.15	.02	.07	.13	.02	.08	.14
Fuel economy, mi/10^6 btu:									
Emission cycle	9.3	9.1	8.9	10.0	9.7	9.7	10.4	10.0	10.0
Highway cycle	15.8	15.3	14.8	15.9	15.2	14.8	16.0	15.9	15.7

into incipient misfire under some conditions. The same effect--that is, relatively low HC emissions during cold operation but increased HC emissions during high temperature operation--may also be expected from a high vapor pressure fuel. In an effort to determine the vapor pressure effect, cumulative hydrocarbon emissions were measured at various intervals throughout the test. Of particular interest was the first 40 seconds of the hot-start portion of the test cycle. Data for vehicles A and B (figure 3) show total HC to be appreciably increased during the hot-start portion with the increase being greatest for the methanol blends at high ambient temperature.

Bag samples were collected and analyzed during the hot-start portion of the tests. Analyses showed that, of the total hydrocarbons, approximately 90 pct was unburned methanol. The high concentration of methanol during this portion of the tests possibly was due to methanol or methanol/hydrocarbon azeotropes being evaporated from the carburetor and absorbed in the charcoal canister during the "hot-soak" period. This material subsequently is desorbed from the charcoal after engine startup and serves to enrich the mixture for a portion of the test cycle.

Methanol Emissions

The amount of unburned methanol in the exhaust is closely related to the amount of methanol in the fuel. However, slightly higher unburned methanol emissions were observed for tests at the higher temperatures. Unburned methanol in the exhaust was found to be 2 to 5 pct of the total HC when using 5 pct methanol and 7 to 9 pct of the total HC when using 10 pct methanol.

Although an assessment of the effect of the methanol emissions is beyond the scope of this report, some comment may be in order. Methanol is essentially unreactive in the photochemistry of smog formation (2); therefore, the unburned methanol may not be significantly objectionable as a source of photochemical feed. With respect to the toxicity of the unburned methanol itself,

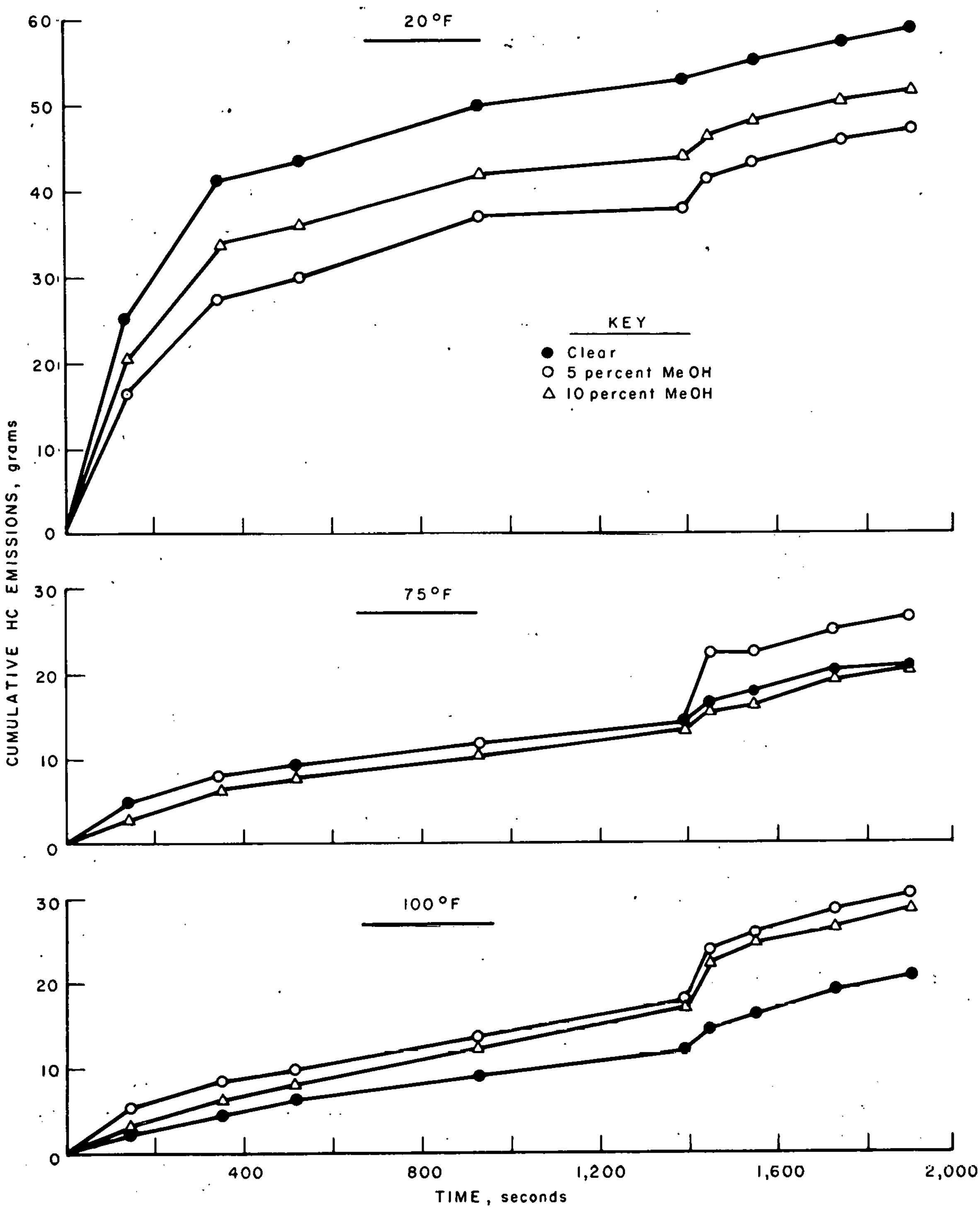

FIGURE 3. - Cumulative HC Emissions--1975 Federal Cold Start Emission Test Cycle

the undiluted exhaust of a vehicle operating on 10 pct methanol may contain methanol at a concentration less than one-half of the threshold limit value (TLV) for methanol in air. These observations would suggest that the unburned methanol may not be objectionable but the question should be considered in greater depth before being dismissed.

Aldehyde Emissions

Aldehydes in the exhaust were found generally to increase with higher concentration of methanol in the fuel. Although the percentage increase of exhaust aldehydes is appreciable with methanol fuel blends, the absolute increase is small; comparative values should be kept in this perspective.

Comparative data from catalyst and noncatalyst vehicles (table 5) show catalytic treatment highly effective in reducing both the methanol and the aldehyde emissions.

TABLE 5. - Exhaust aldehydes and unburned methanol--catalyst and noncatalyst-equipped vehicles

Emissions, g/mile	Ambient temperature, °F								
	20			75			100		
	Clear fuel	5% MeOH	10% MeOH	Clear fuel	5% MeOH	10% MeOH	Clear fuel	5% MeOH	10% MeOH
	CATALYST-EQUIPPED VEHICLES (D, E, H, I)								
Aldehydes...	0.02	0.02	0.06	0.02	0.02	0.03	0.02	0.03	0.04
Unburned methanol..	.01	.05	.06	.01	.02	.03	.01	.04	.07
	NONCATALYST-EQUIPPED VEHICLES (A, B, C, F, G, J)								
Aldehydes...	0.18	0.19	0.23	0.16	0.16	0.19	0.15	0.16	0.17
Unburned methanol..	.02	.08	.21	.02	.10	.20	.02	.13	.18

Nitrogen Oxides Emissions

Levels of NO_x emissions were unaffected by the amount of methanol in the fuel but were slightly reduced as the ambient test temperature was increased and slightly increased at cold ambient temperature. It was postulated that methanol in the fuel might reduce NO_x via either or both of two mechanisms: (1) effectively leaning the fuel mixture, or (2) as a consequence of additional charge cooling associated with the high heat of vaporization of methanol. Assuming an initially lean engine, either would serve to reduce peak combustion temperature. That the anticipated effect was not observed would be explained if A/F mixtures of the stock cars were richer than the A/F associated with peak NO_x. Further leaning the fuel mixture by methanol addition then would tend to increase NO_x and offset the influence of the charge-cooling effect toward lower NO_x.

Carbon Monoxide Emissions

Carbon monoxide was substantially reduced by the addition of methanol to the base fuel at cold and median ambient temperatures. At high ambient temperature, CO emissions levels varied erratically, but, in general, the fuels containing methanol produced higher CO levels than the base fuels. The effect is greater with the high-vapor-pressure test fuel than with the commercial stock--suggesting that increased CO at elevated temperature is due to evolution of fuel vapor from carburetor fuel. This vapor discharged directly with the intake can significantly enrich the mixture. The effect is clearly shown in the individual mode data (table 6) wherein hot-start CO emissions may be equal to or greater than CO emissions during cold-start conditions.

TABLE 6. - CO emissions by test mode--test vehicles A through J

Carbon monoxide emissions, g/test	Ambient temperature, °F								
	20			75			100		
	Clear fuel	5% MeOH	10% MeOH	Clear fuel	5% MeOH	10% MeOH	Clear fuel	5% MeOH	10% MeOH
Cold transient	462.0	514.7	444.3	114.9	85.9	78.0	78.9	62.1	47.4
Stabilized	41.9	22.5	17.0	30.3	19.5	36.2	36.2	58.6	41.5
Hot transient	32.2	22.9	18.6	37.5	34.3	28.5	49.9	91.7	65.4

A conclusion to be drawn from the CO emissions data is that for summer grade U.S. fuels the front-end volatility of gasoline for use in blend with methanol should be adjusted downward from historical values. This does then raise questions about disposition of the fuel light ends that are displaced.

Fuel Economy

The average fuel economy of all vehicles tested (based on fuel energy input) generally was found to decrease slightly with methanol addition. Although the decrease in fuel economy was up to 10 pct in some cases, the data must be interpreted with care since the averages include results from a selection of test vehicles among which fuel economy differed widely. Fuel-economy data for individual vehicles (75° F tests) shows that the fuel-economy change due to methanol is vehicle sensitive but usually follows the trend shown by the average data. Other researchers have shown that fuel energy economy either increased or decreased by addition of methanol to gasoline used in pre-1974 model vehicles. Results of our studies would indicate that a finding of gain or loss with methanol addition would depend upon whether the vehicles were initially adjusted fuel rich or fuel lean.

Other researchers (as well as other work described later herein) have shown that in order to maintain minimum timing for best torque (MBT) as A/F is adjusted progressively leaner, spark timing must be advanded. Therefore, in late-model vehicles that, for purposes of emission control normally operate both slightly lean and with timing retarded from MBT, mixture enleanment due to methanol addition may effectively further displace ignition timing from MBT to result in reduced fuel economy. In brief, results of the present study suggest that the addition of methanol to gasoline used in 1975 model vehicles is not expected to result in improved fuel economy. Other work described later herein suggests that engines optimized for methanol/gasoline operation produce equivalent fuel energy economy as engines similarily optimized for gasoline operation.

Complete emission/fuel-economy data for each vehicle/fuel combination are given in tables A-1 through A-15. Fuel economy-data for the vehicles at varied ambient temperature and for varied methanol levels are displayed in figure 4.

EXTENDED SERVICE TESTS

Five test vehicles were driven for an extended period, each using 10 pct methanol fuel blend in a commercial gasoline. The gasoline was purchased from a refinery in the early winter, blended with methanol, and stored in new above-ground fuel tanks. The fuel supply was used from early winter to late July with typical local seasonal temperature variations; these ranged from a minimum temperature of about 15° F in winter to a maximum about 100° F in summer. During the winter season, which may have been expected to pose temperature-related phase separation problems, fuel in the storage

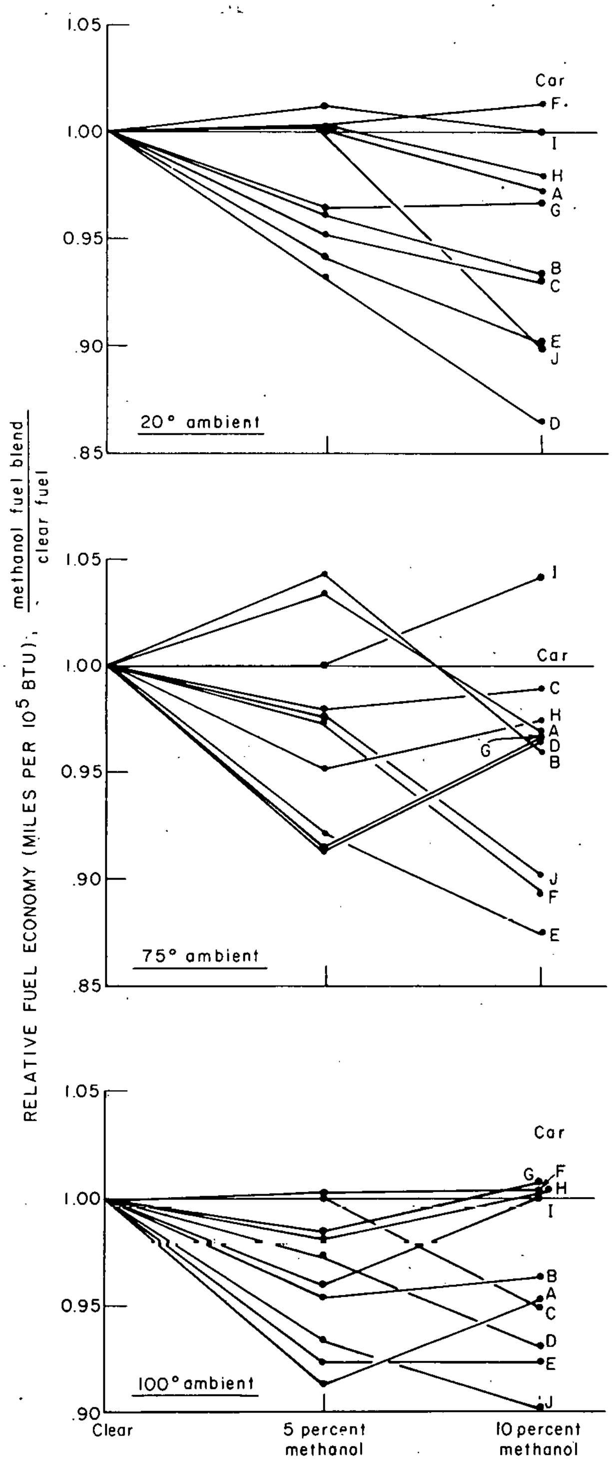

FIGURE 4. - Methanol/Gasoline Fuel Economy Relative to Gasoline Fuel Economy.

tanks collected water at a slow rate--probably explained by low absolute humidity and narrow temperature fluctuations. During the spring and summer conditions, however, water absorbed by the methanol in the fuel increased from about 100 to 700 ppm with an accompanying phase-separation temperature change from 18° to 48° F. Although this may represent a "worst case" situation, it does point out that special care and handling will be necessary using methanol-blended fuel.

Vehicle mileage accumulation consisted of 8 hours per day operation driving the vehicle 1 hour on a city route approximating the federal emission cycle followed by 1 hour of open highway driving at posted speed limits. Emission tests were made at 0; 1,000; 3,000; and 5,000 miles. Modified road-octane requirement tests were made at the start and at the end of the mileage tests; these consisted of obtaining trace knock during wide-open-throttle accelerations using isooctane/heptane reference fuels. At the completion of the tests, the engines were disassembled, and all combustion chamber and fuel handling components were inspected for corrosion, deposits, and dimensional or other change in materials.

The engine in vehicle A (which had approximately 10,000 miles prior use) was disassembled and cleaned prior to use with the 10 pct methanol fuel blend. After 5,000 miles operation with the 10 pct methanol, the engine was again disassembled and inspected. The combustion chamber deposits which had formed were judged to be very light and probably equal to or less than those expected from operation with gasoline. However, the carburetor butterfly plates were discolored with numerous "rust type" spots.

Vehicles D, H, and J had approximately 2,500 miles "breakin" use with typical unleaded fuels before entering the test program. Of this group, vehicles D and J accumulated 7,500 miles and vehicle H accumulated approximately 10,000 miles using 10 pct methanol.

Prior to entry into the methanol work, the engine in vehicle K had been used for approximately 10,000 miles in tests with typical unleaded fuels. Upon entry into the methanol work the engine was disassembled and examined. Deposits were noted but left intact. After 5,000 miles use with 10 pct methanol, the engine was again disassembled and examined.

No consistent directional change was observed for exhaust emissions, fuel economy, or octane requirement during the mileage accumulation (table 7). None of the vehicles failed to operate due to engine malfunction or phase separation within the fuel mixture. The most noticeable difference in vehicle operation using the 10 pct methanol in the vehicle was a hesitation when the throttle was slightly depressed. Otherwise, no cold-starting or vapor-locking problems were encountered. With respect to combustion cleanliness, the experiences would suggest that 10 pct methanol in the fuel may not clean deposits from an engine, but may aid in slowing deposit formation. Overall, no serious problems were associated with the use of methanol in the fuel; the major benefit was seen in the methanol's service as an aid to reduce engine deposit formation.

TABLE 7. - Exhaust emissions and fuel economy (10 pct methanol, extended service)

Elapsed miles	Emissions, g/mile					Fuel economy, mi/gal	
	CO	HC	NO_x	Aldehydes	Methanol	Urban	Highway
VEHICLE A							
0	14.8	2.3	1.4	0.20	0.29	8.4	14.1
1000	17.7	2.2	1.3	-	.22	9.0	15.9
3000	16.1	2.1	1.3	.23	.22	9.3	16.4
5000	18.2	2.4	1.2	.18	.14	9.4	16.6
VEHICLE D							
0	11.8	1.1	2.0	0.02	0.05	14.9	21.7
1000	11.2	.9	1.7	.02	.04	14.3	21.3
3000	12.5	1.0	1.8	.02	.04	14.2	20.0
5000	12.6	1.0	2.2	.05	.05	12.3	17.5
7500	13.1	1.1	1.9	.02	.05	14.8	20.7
VEHICLE H							
0	3.0	0.8	2.1	0.02	0.03	9.5	14.6
1000	3.0	.8	2.0	.02	.01	9.9	15.5
3000	2.4	1.1	2.2	.05	.03	9.0	14.5
5000	3.7	1.0	1.9	.05	.04	9.5	15.2
7500	3.3	1.2	2.4	.05	.01	9.3	14.6
9700	2.7	1.3	1.9	.06	.06	9.3	14.7
VEHICLE J							
0	8.8	1.8	1.8	0.21	0.14	10.5	16.7
1000	9.5	1.6	1.8	.21	.13	9.9	16.8
3000	12.0	1.3	3.1	.15	.14	10.6	18.8
5000	11.1	1.5	2.8	.18	.14	10.1	17.0
7500							
VEHICLE K							
0	8.3	2.9	3.0	-	0.28	9.9	16.7
1000	8.5	2.3	3.1	-	.26	10.0	18.2
3000	6.2	2.4	3.0	-	.22	9.1	16.9
5000	8.5	2.5	3.2	-	.21	9.6	17.3

VEHICLE OPTIMIZATION FOR METHANOL/GASOLINE BLENDS

Experimental data were obtained using a stationary 1975 350-cubic-inch-displacement (CID) engine to obtain an indication of optimum conditions for best fuel economy with each methanol concentration. Results with this engine showed conditions for optimum fuel economy to range from 1.1 to 1.25 A/F equivalence ratio with MBT timing. A slight improvement in fuel economy was noted without the use of exhaust gas recirculation (EGR); however, the MBT timing point was shifted depending on the use of EGR.

Air-fuel mixture was optimized for each fuel blend by adjusting to provide 1.1 to 1.2 A/F equivalence ratio at idle; 1,200; 1,600; 2,200 engine rpm. Ignition timing was retarded from MBT as necessary to control NO_x emissions to 2 g/mile; EGR and ignition timing were varied to determine which NO_x control method (EGR or spark retard) resulted in the least fuel penalty.

Emission/fuel-economy cycle test data (table 8) show a slight gain in fuel economy by using EGR and best ignition timing as opposed to spark retard alone; that is, without EGR. Results by others have suggested similar findings (3). With this background for guidance, the tests were conducted with EGR, and the standard advance curve was used except for adjustment of basic timing to result in 45° advance at 55 mph with EGR.

TABLE 8. - Exhaust emissions and fuel economy (2 grams NO_x, best fuel economy

Pct MeOH in fuel	A/F Eq.[1] ratio	Emissions, g/mile				Fuel rate, mpg[1]		Fuel rate, m/10^5 BTU[1]	
		CO	HC	NO_x	Aldehydes	Urban	Highway	Urban	Highway
Clear	1.18	4.11	0.65	1.90	0.03	12.6	19.1	10.9	16.5
5	1.19	2.32	.62	1.88	.03	12.3	18.8	10.9	16.7
10	1.13	4.92	.60	1.83	.04	12.6	18.5	11.5	16.9
15	1.13	2.84	.65	1.94	.03	12.0	17.8	11.3	16.7

[1] Average for idle 600; 1,200; 1,600; 2,200 rpm steady-state.
[2] Represents average of three replicate tests.

The emission/fuel-economy data for the vehicle optimized as described for clear, 5, 10, and 15 pct methanol show essentially equivalent fuel economy (based on an available energy basis) for each of the fuels with the engine adjusted to provide equivalent emission levels.

ROAD OCTANE TESTS

The high-octane quality of pure methanol is well documented, and much experimental work has been done with single-cylinder CFR engines to provide information on the octane blending value of methanol in methanol/gasoline blends (5). However, road-octane data from late-model vehicles using methanol/gasoline blends are lacking in current literature. To provide some information of this nature, an experimental program was undertaken using current-production vehicles.

Tests were conducted using a six vehicle fleet (vehicles C, D, E, F, I, and J) with engine size ranging from 140 to 351-CID. The test procedure was to run modified Uniontown road-octane tests (6) comparing test fuels with mixtures of isooctane and heptane. Test fuels consisted of three base fuels of 84, 87, and 91 research octane number (RON) each with 0, 5, 10, and 15 pct methanol in gasoline. In an effort to maintain similar base fuel composition, the base fuels consisted of an unleaded, low-octane Indolene for the 91 RON base fuel and mixtures of 12.5 and 25 pct of a low-octane, full-boiling-range stock in Indolene to provide the 87 and 84 RON base fuels, respectively.

Figure 5 presents results with data for all vehicles averaged. These data show octane improvement with the low-octane base fuel as much greater than that with the high-octane base fuel. Fifteen pct methanol in the low-octane base fuel resulted in 7.3 road-octane-number increase compared to a 3.8 road-octane-number improvement with the high-octane base fuel. Road-octane data from the individual vehicles are given in table 9.

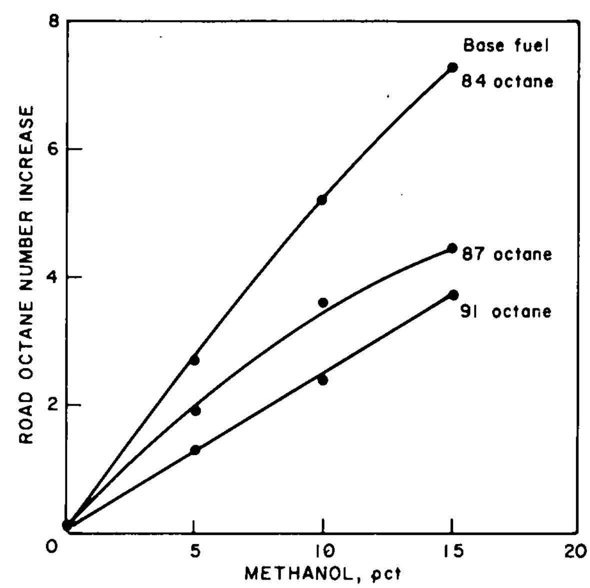

FIGURE 5. - Octane Quality Increase Due to Methanol Addition to Gasoline (Average 6 Vehicles).

The blending octane values (BOV) of methanol in the methanol/gasoline blends are calculated and presented in table 10. The blending octane value is defined as follows:

$$BOV = \frac{BON - N_f(1-X)}{X}$$

where BOV = Blending octane value,
BON = Blend octane number,
N_f = Octane number of base fuel, and
X = Volume fraction of methanol in blend.

Other researchers have shown that when considering fuels with a wide range of methanol content BOV is a strong function of the volume fraction of methanol in the fuel. However, over the range typically considered as practicable for automotive use (5 to 15 pct methanol) the BOV, based on road octane, was shown to be relatively insensitive to methanol fuel level and highly dependent on the octane of the base fuel. The average BOV of methanol, based on road octane, ranged from 114 for the 91 RON base fuel to 132 for the 84 RON base fuel. Blending octane value of methanol was also shown to be sensitive to test vehicles as evidenced by a spread of 30-40 BOV numbers within the six car test fleet for a single test fuel.

TABLE 9. - Road octane quality of methanol/gasoline mixtures

Fuel	Modified Uniontown road octane rating Vehicle engine displacement, CID					
	140	250	262	318	351	350
91 RON base fuel:						
clear..........	88.5	88.7	89.2	87.8	87.0	89.8
+5% MeOH........	90.2	89.2	92.1	89.1	87.7	90.8
+10% MeOH.......	91.6	89.8	93.8	90.1	88.4	91.9
+15% MeOH.......	92.6	91.0	95.5	91.3	89.9	93.5
87 RON base fuel:						
clear..........	86.5	86.6	86.0	86.4	85.2	87.5
+5% MeOH........	89.0	88.0	88.9	88.1	85.9	89.0
+10% MeOH.......	91.2	88.9	91.8	90.0	87.3	90.1
+15% MeOH.......	92.0	89.6	92.8	90.8	88.0	92.0
84 RON base fuel:						
clear..........	81.2	83.6	81.5	84.0	81.9	84.2
+5% MeOH........	84.9	85.9	84.3	86.3	84.0	86.1
+10% MeOH.......	88.3	88.0	88.3	88.7	85.9	88.1
+15% MeOH.......	91.8	88.8	91.0	90.4	87.9	90.1

TABLE 10. - Blending octane value of methanol in methanol/gasoline mixtures

Fuel	BOV methanol (based on road octane rating) Vehicle engine displacement, CID						
	140	250	262	318	351	350	Average all vehicles
91 RON base fuel:							
+5% MeOH........	122	99	147	114	101	104	114
+10% MeOH.......	120	100	135	110	101	111	113
+15% MeOH.......	116	104	131	111	106	115	114
87 RON base fuel:							
+5% MeOH........	137	115	144	120	99	118	122
+10% MeOH.......	134	110	144	122	106	114	117
+15% MeOH.......	123	107	131	116	104	118	116
84 RON base fuel:							
+5% MeOH........	150	130	137	130	123	122	132
+10% MeOH.......	152	128	150	131	122	123	134
+15% MeOH.......	152	118	145	127	122	124	131

Methanol addition to gasoline without changing carburetion effectively results in an A/F that is leaner than would be found with straight gasoline. In order to determine if mixture enleanment due to methanol addition caused perturbation in road octane requirement, road octane tests were conducted with each of three vehicles (E, F, and I) with A/F approximately 13, 15, and 17 at wide-open-throttle (WOT). Road octane data based only on three vehicles must be considered inconclusive and treated cautiously, but major trends may appear regardless of the limited sampling. Results (table 11) suggest a trend toward increased road octane requirement at leaner A/F mixtures for two of the vehicles, whereas the third vehicle suggested decreased road octane requirement with the leaner A/F. Although the findings are inconclusive, they do suggest vehicle road octane requirement varies considerably with vehicles and is not consistently affected by A/F in the range tested.

TABLE 11. - Road octane quality of methanol/gasoline mixtures at varied air-fuel ratio

	Modified Uniontown road octane rating								
	Vehicle I (262-CID)			Vehicle F (351-CID)			Vehicle E (350-CID)		
	A/F ratio, WOT			A/F ratio, WOT			A/F ratio, WOT		
	13	15	17	13	14	16	13	15	16
91 RON base fuel:									
clear	89.2	89.0	91.1	87.0	88.5	89.0	89.8	87.0	85.5
+5% MeOH	92.1	91.5	91.9	87.7	89.0	90.1	90.8	88.5	87.0
+10% MeOH	93.8	94.2	94.1	88.4	89.8	91.0	91.9	90.5	90.1
+15% MeOH	95.5	96.5	96.0	89.9	90.3	92.0	93.5	93.7	93.3
87 RON base fuel:									
clear	86.0	86.5	88.1	85.2	85.5	87.0	87.5	84.5	84.0
+5% MeOH	88.9	88.9	90.5	85.9	87.0	88.2	89.0	87.0	86.0
+10% MeOH	91.8	92.1	93.0	87.3	88.4	89.2	90.0	90.0	89.0
+15% MeOH	92.8	94.9	95.4	88.0	89.2	90.5	92.0	93.0	92.0
84 RON base fuel:									
clear	81.5	82.9	83.2	81.9	83.0	82.5	84.2	82.5	82.0
+5% MeOH	84.3	86.2	87.5	84.0	84.5	84.8	86.1	85.5	84.2
+10% MeOH	88.3	89.8	90.4	85.9	86.5	87.0	88.1	87.5	87.1
+15% MeOH	91.0	92.8	93.5	87.9	88.0	88.5	90.1	90.8	90.4

The blending octane values of methanol in methanol/gasoline mixtures are calculated, averaged, and presented in table 12. The data suggest that the BOV of methanol may be reduced at A/F near 13 compared to the leaner conditions, especially using the low-octane base fuel. Blending octane value of methanol was also shown to be dependent on base fuel at all A/F tested.

PERFORMANCE MAPPING--METHANOL, METHANOL/GASOLINE BLENDS

An emissions/fuel-economy map was generated both using methanol and methanol/gasoline fuel blends in a 1975 model 350-CID engine mounted on a test stand and coupled to an eddy-current dynamometer through an automatic transmission. Exhaust emissions and fuel rate were determined at steady-state operating conditions.

TABLE 12. - Blending octane value of methanol in methanol/gasoline mixtures

Air-fuel ratio WOT	Average blending octane value,[1] methanol								
	91 RON base fuel			87 RON base fuel			84 RON base fuel		
	5% MeOH	10% MeOH	15% MeOH	5% MeOH	10% MeOH	15% MeOH	5% MeOH	10% MeOH	15% MeOH
13	119	116	117	120	121	118	128	132	130
15	119	122	124	128	124	131	135	134	134
16	118	120	123	124	127	128	141	139	138

[1]Based on modified Uniontown road octane rating (average of vehicles E, F, I)

The engine test parameters included the following:

Engine speed:	600; 1,200; 1,600; and 2,200 rpm
Power output:	Road load (1,200 rpm-12 hp; 1,600 rpm-16.3 hp; 2,200 rpm-13.2 hp)
Air fuel:	Air-fuel equivalence settings were varied from 1.1 to the maximum lean-operating limit.
Ignition timing:	Minimum timing for the best torque (experimentally determined) at all compression ratios. In the standard compression ratio (CR) configuration ignition timing was MBT, standard, and retarded approximately 10° from MBT.
EGR:	EGR on and EGR off
Catalyst:	Exhaust was sampled before and after standard oxidation catalyst.
Compression ratio:	8.3 (standard), 9.3, 10
Fuels:	5, 10, and 15 pct MeOH in high-octane, unleaded Indolene plus 100 pct methanol

The base fuel was unleaded, high-octane Indolene; the inspection data for the fuel are presented in table 13.

Air-fuel ratio was controlled by use of a prototype sonic-flow carburetor (Dresserator) chosen for ease in adjusting A/F mixture and for providing good cylinder-to-cylinder fuel distribution. This carburetor was used in conjunction with a high-volume intake manifold (Offenhauser)--a single plane manifold with an exceptionally large volume immediately below the carburetor.

Fuel cylinder-to-cylinder distribution was monitored by sampling the exhaust from each cylinder via a sample probe positioned as near as practicable to the exhaust valve. Even with the sonic-flow carburetor and large intake manifold, fuel maldistribution was found to be a major problem, especially with 100 pct methanol fuel. In order to obtain adequate fuel distribution with 100 pct methanol, it was necessary to reposition the carburetor depending on engine speed or load. Cylinder-to-cylinder fuel distribution was determined for each speed, compression-ratio combination, using both 100 pct methanol and 5 pct methanol prior to emission/fuel-economy measurements. The cylinder-to-cylinder fuel-distribution data are presented in figures A-1 through A-6.

Engine CR changes were accomplished by milling the surface from the engine heads. Engine CR's were not measured but were calculated by assuming that the cylinder heads were a cylindrical area. The fact that the heads were not exactly cylindrical throughout the area removed would result in CR slightly lower than reported. The intake manifold was also necessarily milled to allow proper sealing surfaces.

TABLE 13. - Physical properties of base fuel-emissions mapping tests

Gravity, °API	59.4
Reid vapor pressure, psi	9.0
Research octane No.	96.6
Distillation, ASTM D-86, °F:	
IBP	86
Pct evaporated:	
10	133
50	221
90	315
End point	397
FIA, vol-pct:	
Olefins	7.4
Aromatics	29.5

Optimum ignition timing was experimentally determined for each air-fuel/speed adjustment. The method consisted of first adjusting air-fuel mixture and engine speed to the appropriate test value at approximately the predetermined road-load condition and then, without further carburetion (air or fuel) changes, incrementing ignition timing while maintaining constant engine speed by regulating the power absorbed by the dynamometer. The ignition timing that corresponded to the point that maximum power began to decrease as ignition timing was adjusted toward top dead center (TDC) was defined as MBT. Power differences between the actual road-load power and power at which the MBT point was determined were small and not expected to alter the actual MBT point.

Tests with the standard CR engine were conducted with the ignition timing set at MBT, standard manufacturer's setting, and retarded somewhat from MBT (approximately 10°) to determine the emissions/fuel-economy comparison for vehicles using methanol or methanol/gasoline blends with varied ignition timing. Tests with the higher compression ratio engines were conducted with ignition timing adjusted to MBT for each test condition.

Engine road-load power was determined by reproduction of intake vacuum of the vehicle operated over the road at steady-state conditions with the intake vacuum of the vehicle's engine mounted on a test stand. The measured road-load power agreed with the computer-simulated values based on vehicle weight and frontal area.

THE PERFORMANCE MAP--DISCUSSION

The following discussions summarize our interpretation of data generated at 1,200; 1,600; and 2,200 rpm at MBT timing and without the use of an oxidation catalyst. Results obtained in tests with ignition timing at other than MBT are discussed in a following section. Detailed data are in tables A-16 through A-36.

Figures 6 through 13 present a comparison of emissions and fuel consumption with A/F at various combinations of CR, EGR, and methanol concentration. Figures 6 and 7 present CO and unburned-fuel-emissions data generated at 1,600 rpm and generally represent similar trends at other speeds. Oxides of nitrogen and fuel-consumption data, which are of major interest, are presented for each test speed in figures 8 through 10 (NO_x) and 11 through 13 (fuel consumption).

Fuel Effect

For each unique combination of A/F, CR, EGR, and speed (all held constant between fuels) the addition of methanol at 5, 10, and 15 pct had no effect on CO emission, unburned fuel, or fuel energy consumption. Oxides of nitrogen emission, however, generally decreased slightly as the methanol fuel concentration was increased from 5 to 15 pct.

The use of pure methanol in lieu of gasoline or gasoline/methanol, resulted in CO emissions appreciably lowered and in NO_x emissions lowered by a factor of 2 to 3. Except for the high CR configuration, unburned fuel emissions were generally about the same either using pure methanol or using blends. For the high CR engine configuration, unburned fuel emissions were lower with pure methanol than with blends. Fuel energy consumption using the standard CR engine was about the same or only slightly higher using pure methanol compared to blends; with the high CR configuration, fuel energy consumption was lower when using pure methanol.

Air-Fuel Effect

Carbon monoxide emissions were generally increased as the A/F mixture was adjusted from 10 pct lean to the lean operating limit. The effect was apparent at all speed and CR conditions both with and without exhaust recirculation. However with pure methanol, A/F adjustment in the far-lean region had much less effect toward increased CO emissions.

Unburned fuel emissions were also increased as the A/F was adjusted from 10 pct lean to near the lean operating limit. The increase was consistent both with the methanol/gasoline fuel blends and with pure methanol. The increase was slight in the range of 10 to 20 pct lean with methanol/gasoline blends, and in the range of 10 to 30 pct lean with pure methanol fuel. As the A/F approached the lean operating limit, HC emissions increased rapidly with all fuels. Operation with pure methanol fuel allowed extension of the lean limit to near 50 pct lean compared to 30 to 40 pct lean for the methanol/gasoline mixtures. It should be pointed out that as A/F was adjusted, the

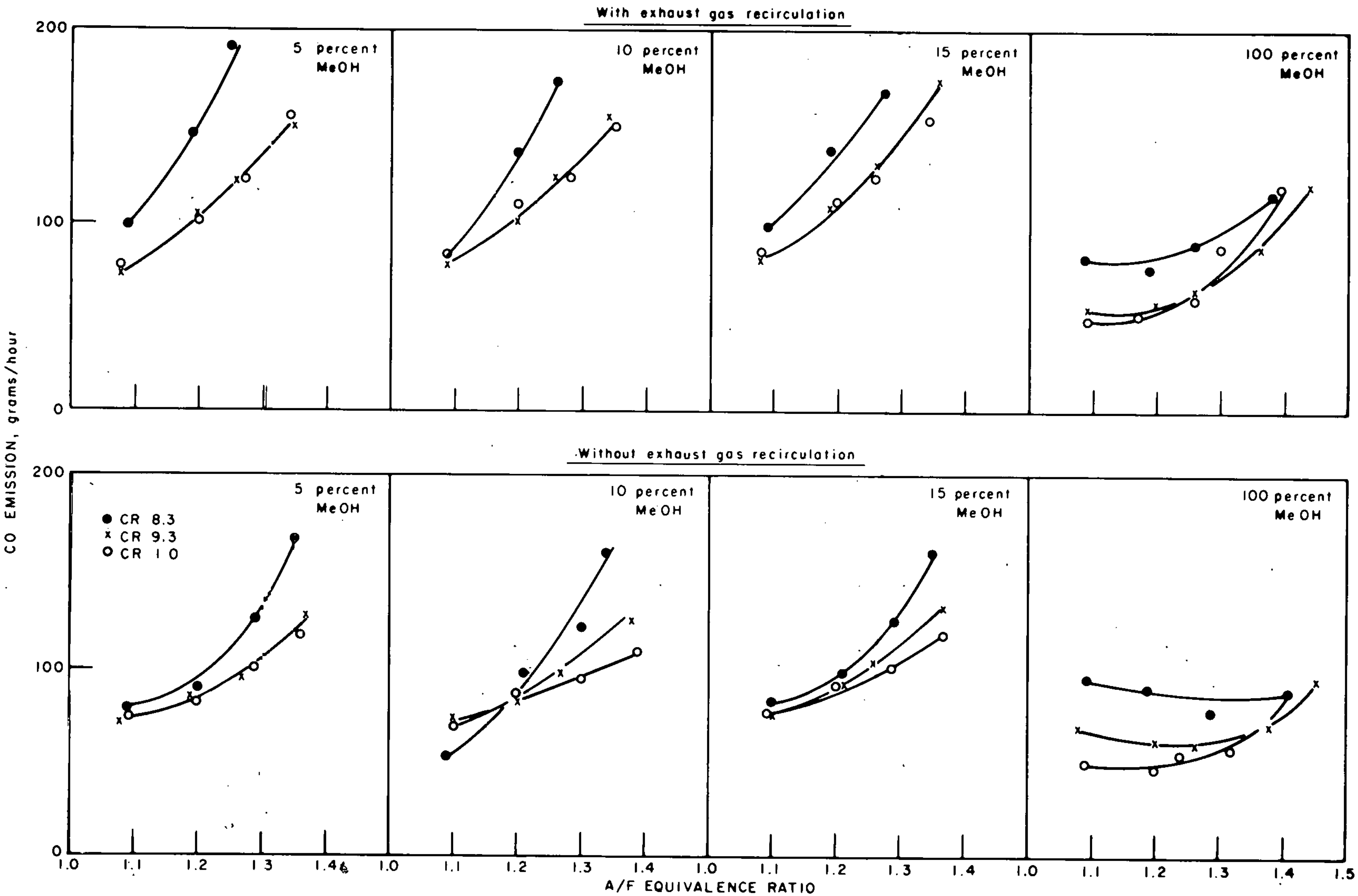

FIGURE 6. - Effect of Air-Fuel Ratio on CO Emissions --1,600 rpm, MBT Timing--

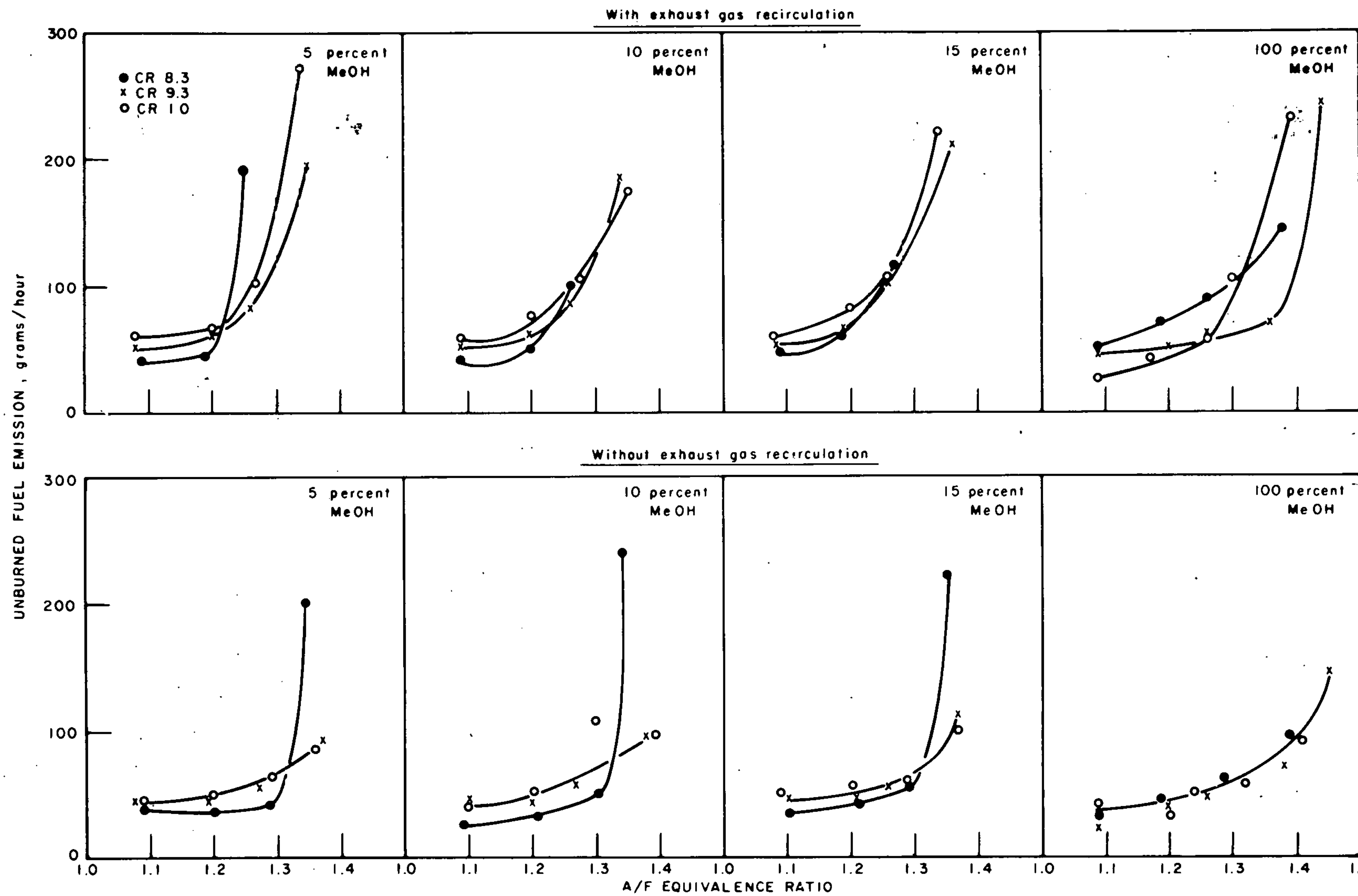

FIGURE 7. - Effect of Air-Fuel Ratio on Unburned Fuel Emissions
--1,600 rpm, MBT Timing--

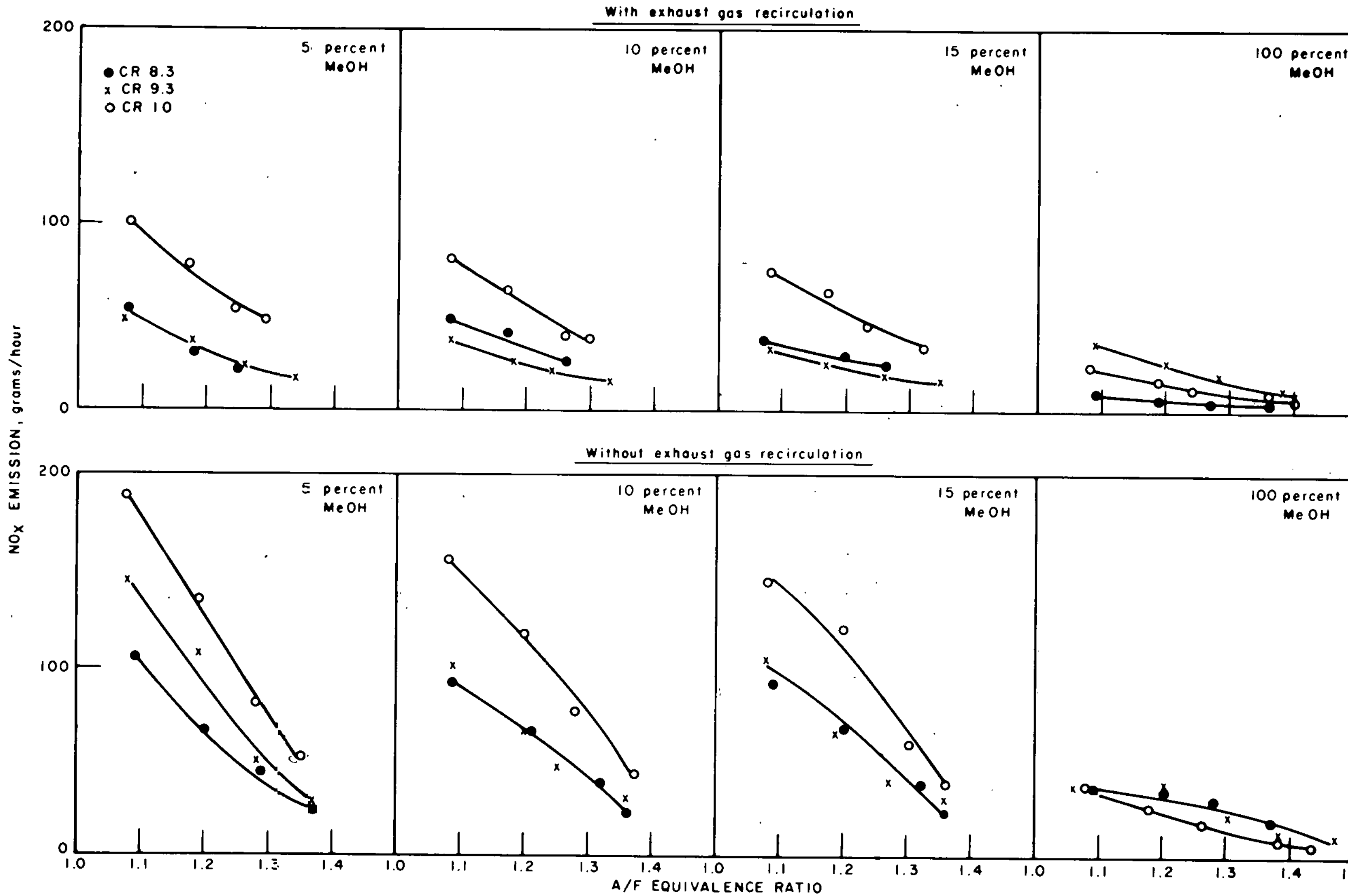

FIGURE 8. - Effect of Air-Fuel Ratio on NO_x Emissions
--1,200 rpm, MBT Timing--

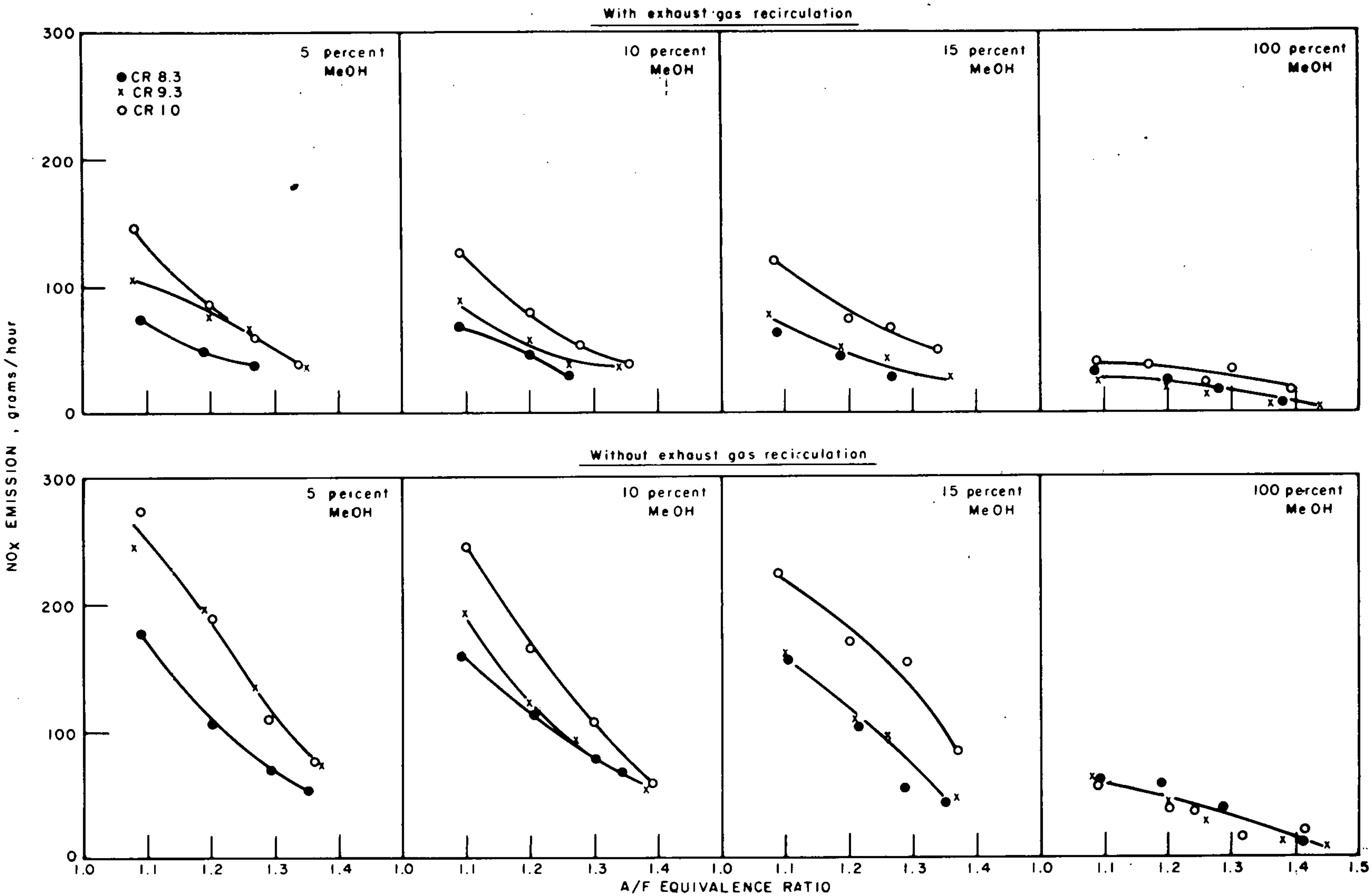

FIGURE 9. - Effect of Air-Fuel Ratio on NO_x Emissions
--1,600 rpm, MBT Timing--

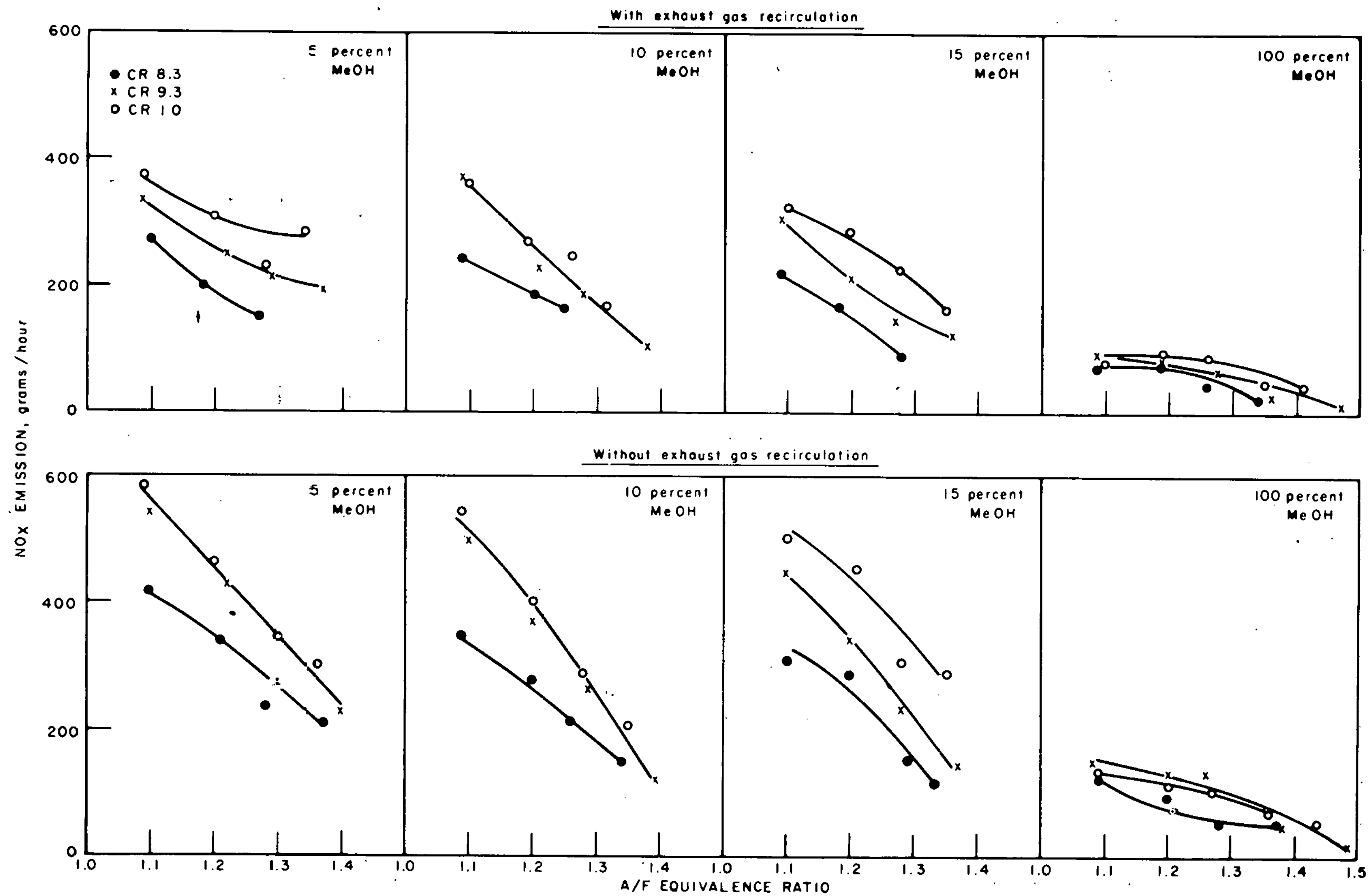

FIGURE 10 . - Effect of Air-Fuel Ratio on NO_x Emissions
--2,200 rpm, MBT Timing--

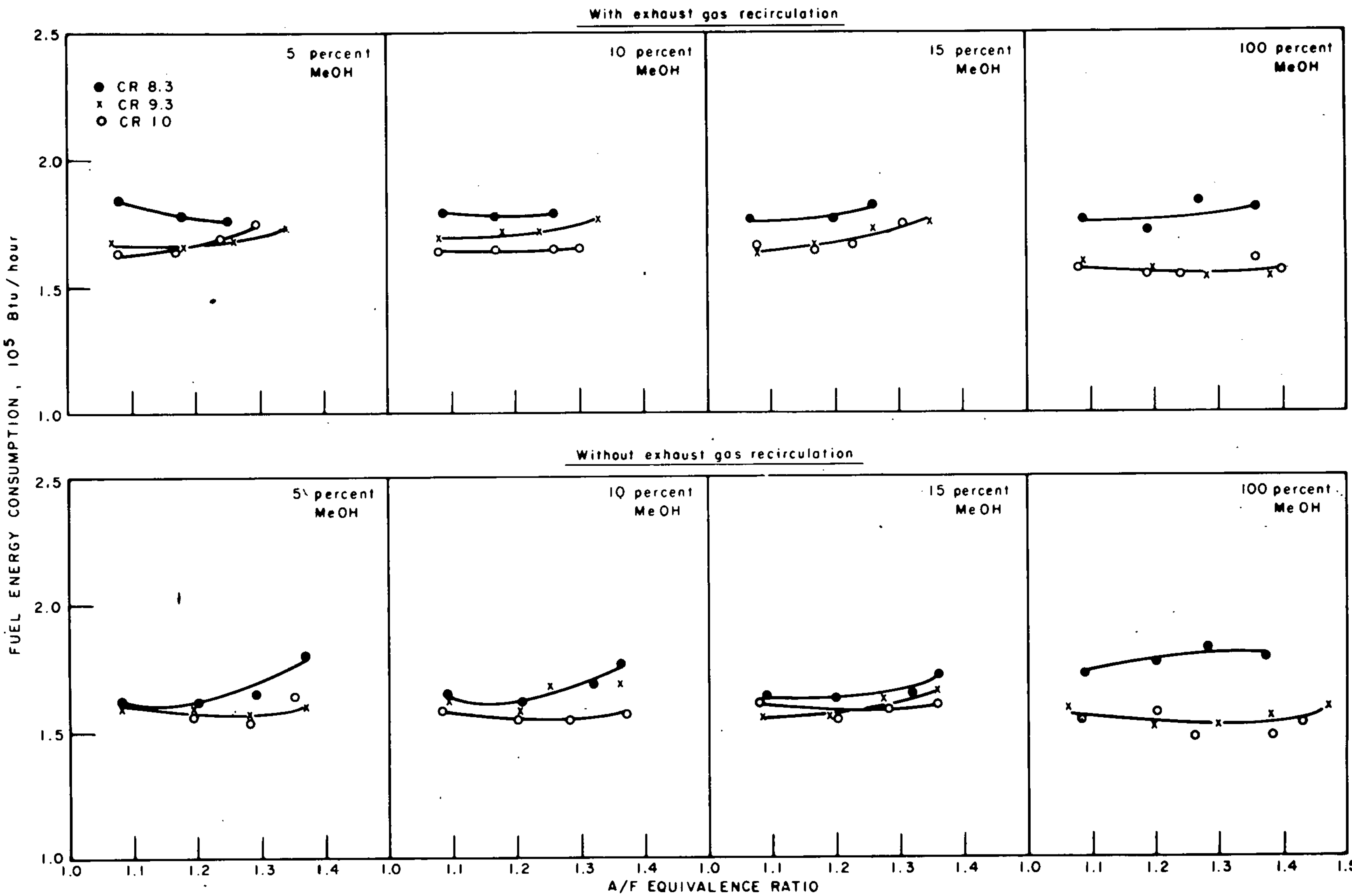

FIGURE 11. - Effect of Air-Fuel Ratio on Fuel Energy Consumption
--1,200 rpm, MBT Timing--

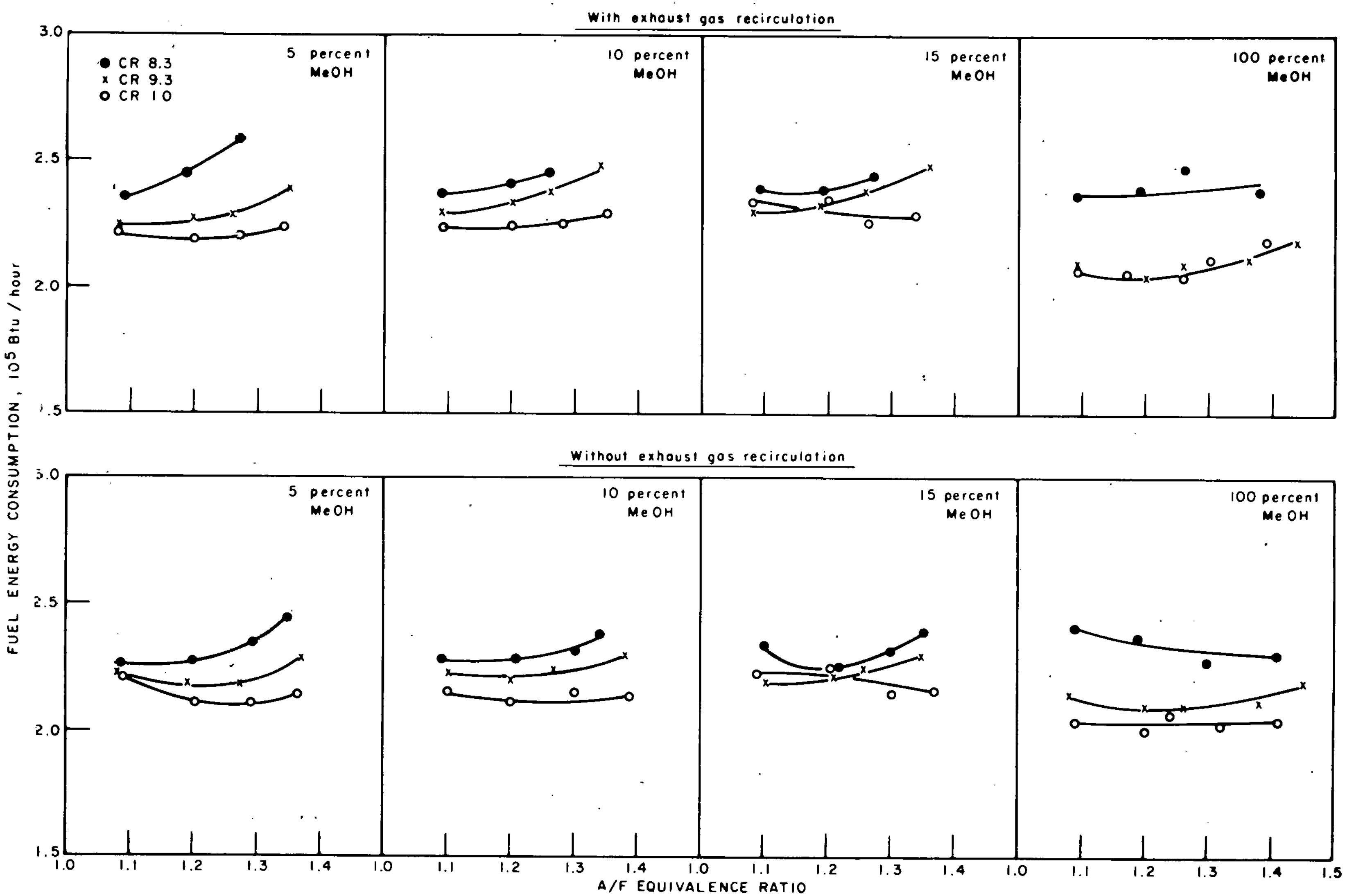

FIGURE 12. - Effect of Air-Fuel Ratio on Fuel Energy Consumption
--1,600 rpm, MBT Timing--

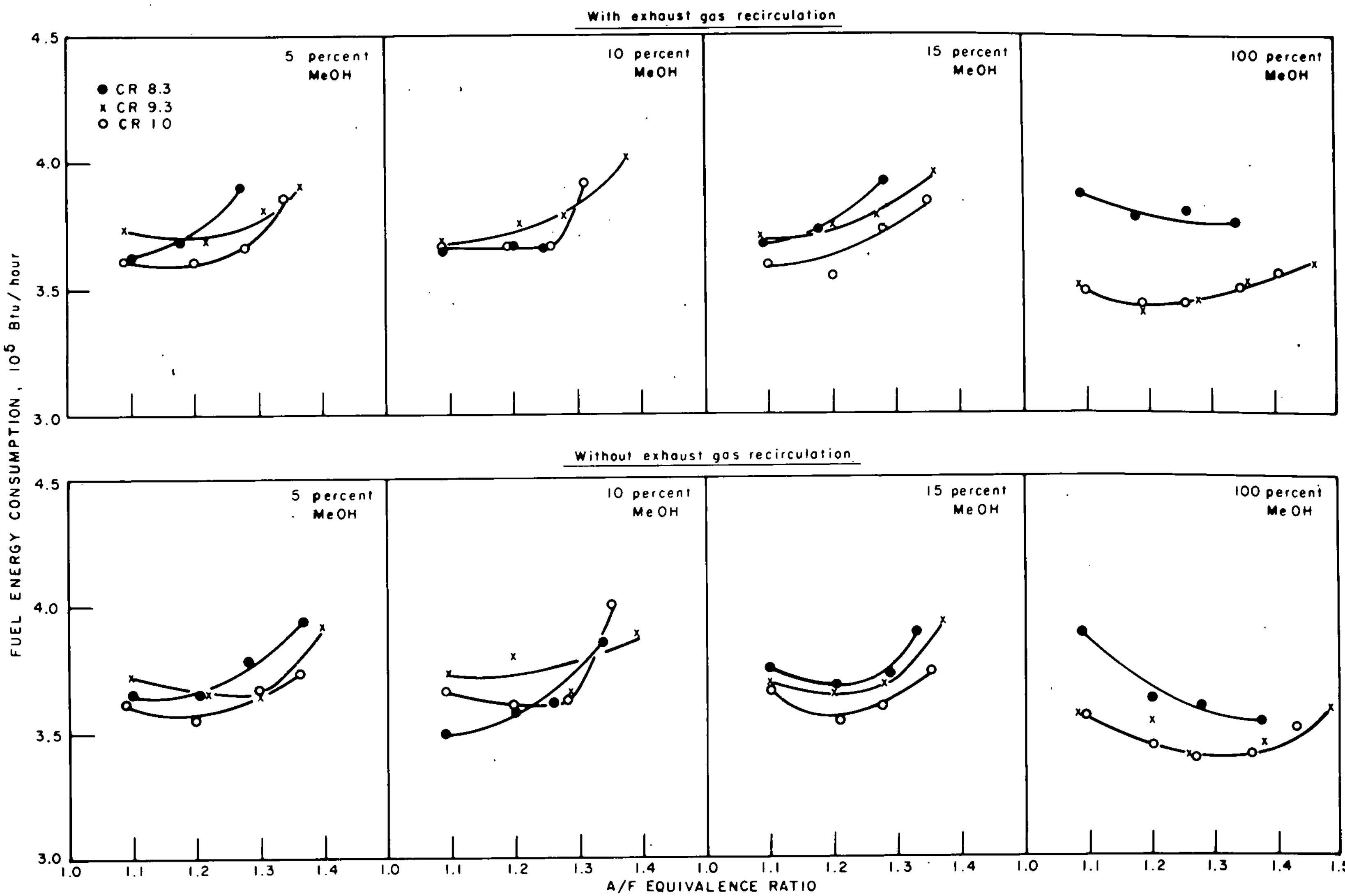

FIGURE 13. - Effect of Air-Fuel Ratio on Fuel Energy Consumption --2,200 rpm, MBT Timing--

ignition timing (which may affect unburned fuel emissions) was also adjusted in order to maintain MBT timing.

Oxides of nitrogen emissions were decreased as the A/F was adjusted from 10 pct lean to the lean operating limit. The effect is substantial and is consistent with each fuel blend as well as with pure methanol. It should be pointed out again that in this series of tests ignition timing was advanced in order to maintain MBT timing as the A/F was leaned. An ignition timing advance characteristically increases NO_x emission while mixture enleanment characteristically reduces NO_x emission. Therefore, it would not necessarily be expected that there be a consistent reduction in NO_x with mixture enleanment while maintaining MBT spark timing.

Fuel energy economy was not consistently affected by change in A/F mixture within the test range of fuel methanol content at MBT timing except for adjustment near the lean operating limit which usually resulted in increased fuel consumption for all fuels.

Compression Ratio Effect

As compared with the standard CR, the high CR configuration using either MeOH or blends generally produced lower CO emissions, higher unburned fuel emissions, higher NO_x emissions, and reduced fuel energy consumption. Notable exceptions to the generalized statement above were observed for methanol/gasoline blends during the low-speed tests with EGR; for these tests unburned fuel emissions were somewhat lower with the high-compression configuration than with the standard engine. The comparable tests with pure methanol suggested no definite trends of unburned fuel emissions with engine CR. It was observed, however, that with the higher CR engines using methanol/gasoline blends operation at slightly leaner A/F was possible before the abrupt increase in unburned fuel emissions near lean limit.

The NO_x increase with higher CR was found much more pronounced with methanol/gasoline blends than with pure methanol for which NO_x emissions typically are very low. Generally stated, a change to higher CR tended to increase NO_x the most at those engine conditions that, of themselves, are associated with high NO_x. These are operation at 10 to 20 pct lean A/F, high speed without EGR. Oxides of nitrogen sensitivity to CR was relatively low with CR change in combination with those engine adjustments typically associated with low NO_x values.

Use of pure MeOH in the high CR engines resulted in 10 to 15 pct decrease in fuel energy consumption from the fuel requirement to using pure MeOH in the standard engine. Results of comparable tests using methanol/gasoline blends suggested a 5 to 10 pct decrease in fuel energy consumption with change to the higher CR.

Exhaust Gas Recirculation Effect

The use of EGR resulted in substantially increased CO emission levels when using methanol/gasoline fuel blends. However, CO emissions were essentially insensitive to EGR when using pure methanol at equivalent test conditions.

Unburned fuel emissions were generally increased by the use of EGR with all fuels. The effect was particularly prominent at low speed; at the higher speeds the EGR influence on unburned fuel emissions became essentially negligible.

Exhaust gas recirculation with MBT timing resulted in substantial NO_x reductions. The effect of EGR was much more pronounced with methanol/gasoline as compared to the effect with pure methanol--following from the fact that with methanol NO_x emissions are low with or without EGR. As expected the effectiveness of EGR in reducing NO_x was found greatly diminished at A/F approaching the lean limit.

A fuel economy penalty of approximately 5 to 10 pct for methanol/gasoline fuel blends was generally associated with EGR. The trend was more pronounced at the lower speeds of 1,200 and 1,600 rpm--less pronounced at 2,200 rpm.

Equivalent tests using pure methanol generally resulted in no fuel economy penalty due to EGR. Some exceptions are to be found--for example, a 5 pct penalty with EGR in the case of the 8.25 CR engine operating at 2,200 rpm; these may, however, be only a reflection of variability in that engine.

Ignition Timing

Data were taken in experiments designed to yield information in the role of spark timing in affecting exhaust emission and fuel economy with methanol and methanol/gasoline blends. For these tests, the engine was used in its standard configuration (8.25 CR). Data were taken operating the engine with A/F from 10 pct lean to the lean limit with and without EGR and with spark timing adjustments (a) to manufacturer's specifications, (b) MBT, and (c) retarded approximately 10° from MBT.

All data are presented in the appendix; selected data are shown graphically in figures 14 through 17. Carbon monoxide emissions (figure 14) are shown independent of ignition timing within the range tested; unburned fuel emissions are highest at the most advanced condition (MBT) and lowest at the most retarded condition (standard). The effect of timing on unburned HC is pronounced with methanol/gasoline blends but negligible using pure methanol. Oxides of nitrogen emissions (figure 16) are approximately doubled by operation at MBT spark timing compared to the standard timing condition. The effect is consistent with each fuel blend both with and without EGR, although the absolute NO_x level is of course lower with EGR.

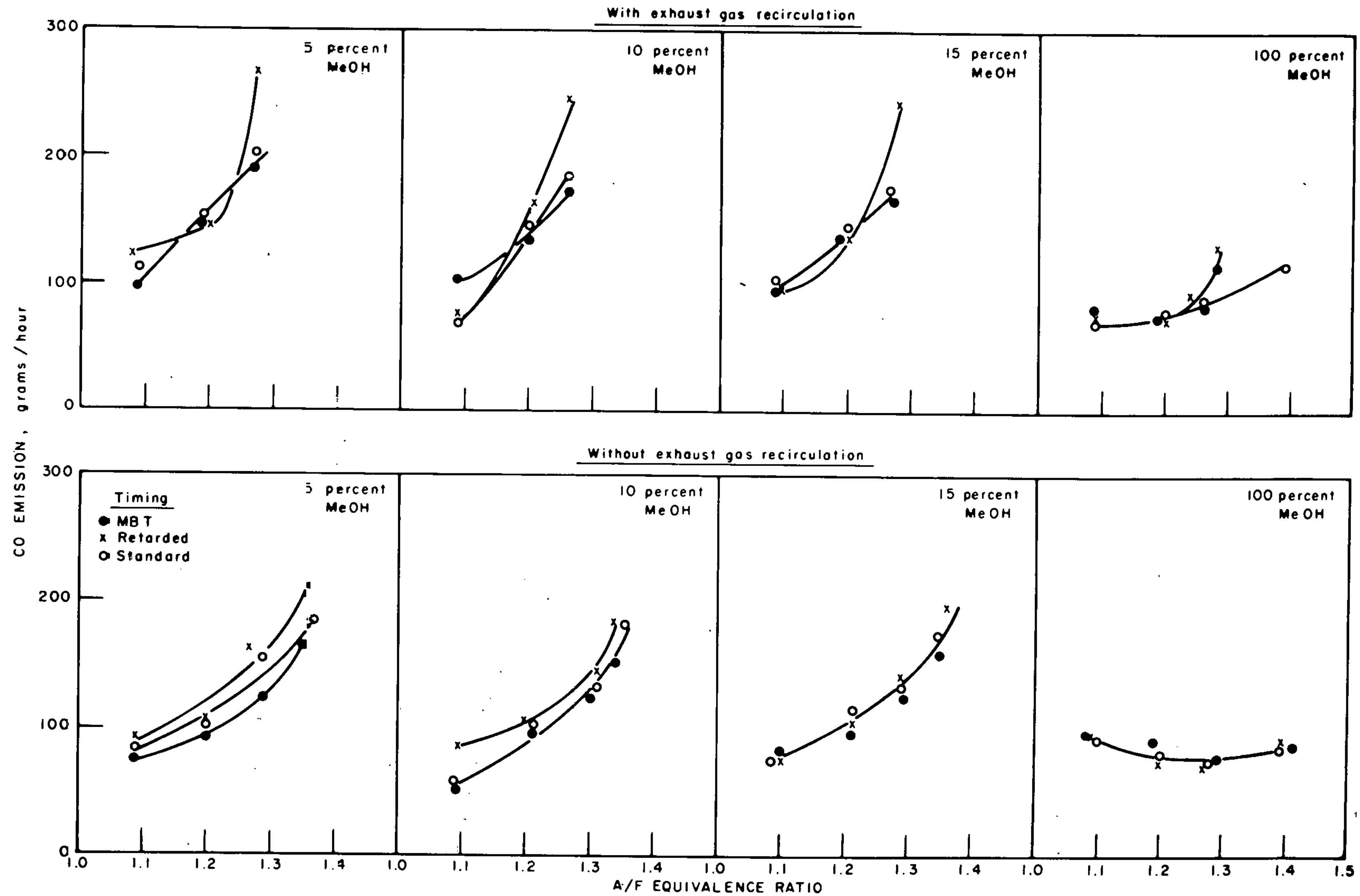

FIGURE 14. - Effect of Air-Fuel Ratio on CO Emissions
--1,600 rpm, Standard CR--

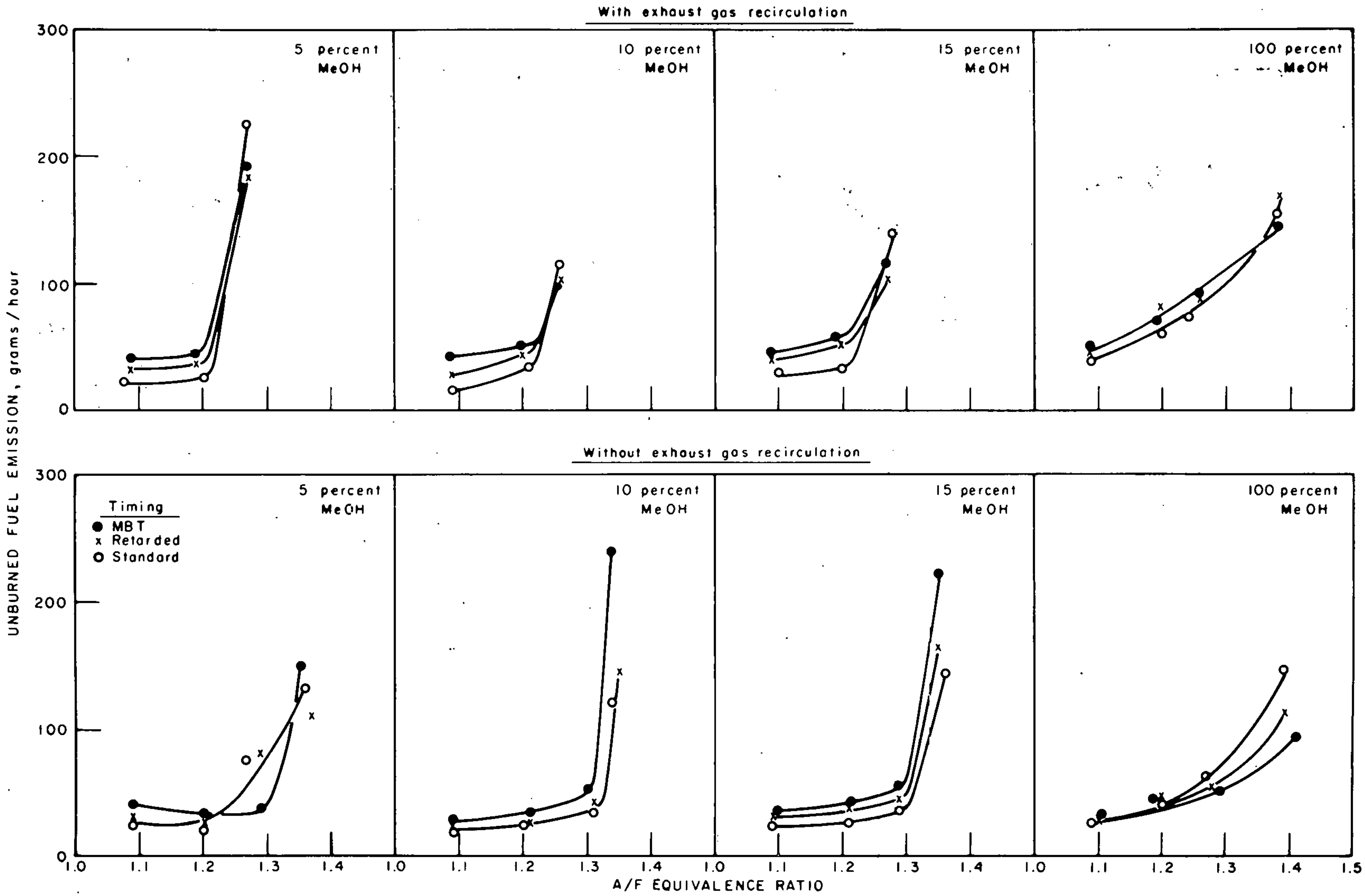

FIGURE 15. - Effect of Air-Fuel Ratio on Unburned Fuel Emissions
--1,600 rpm, Standard CR--

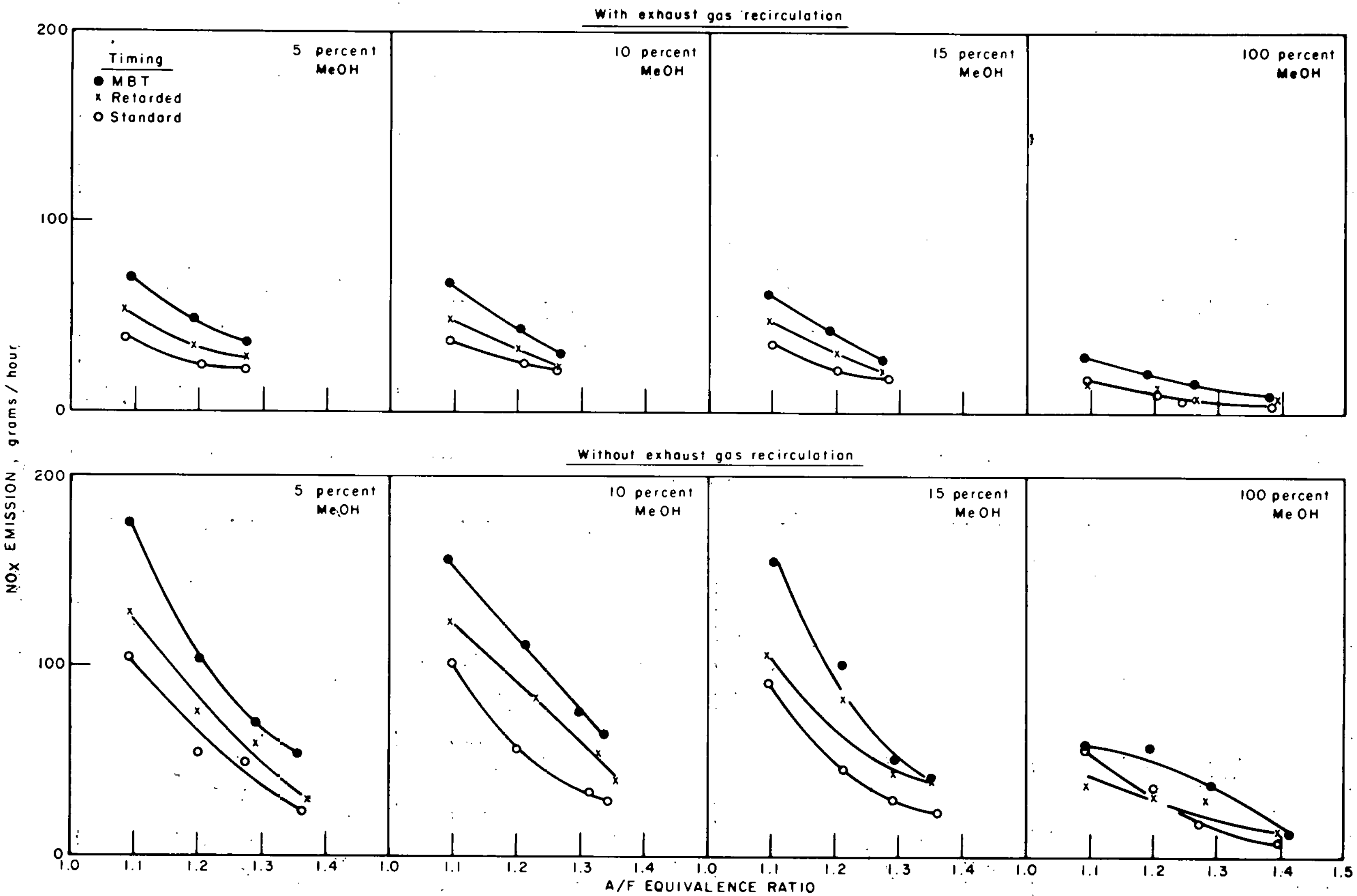

FIGURE 16. - Effect of Air-Fuel Ratio on NO_x Emissions
--1,600 rpm, Standard CR--

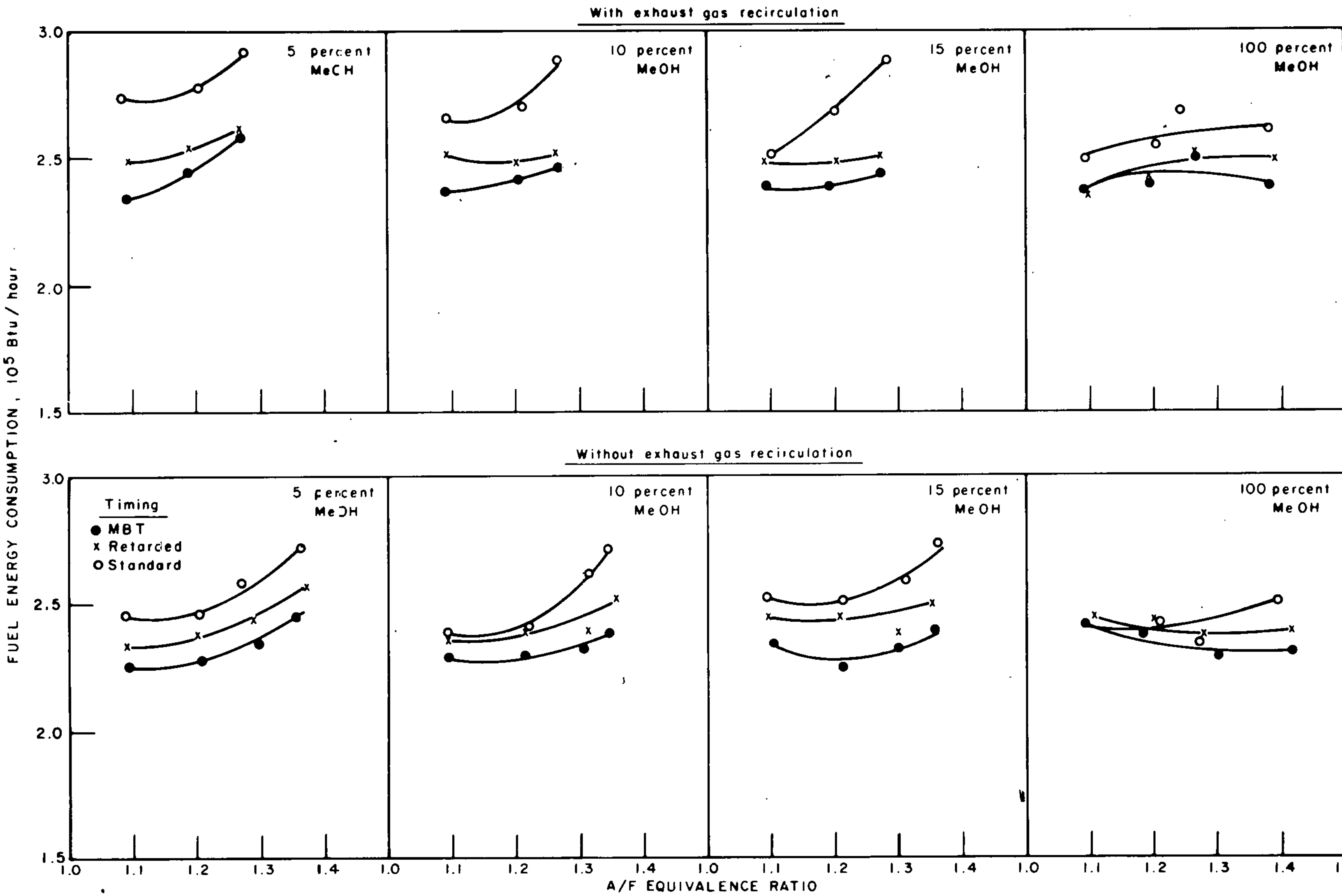

FIGURE 17. - Effect of Air-Fuel Ratio on Fuel Energy Consumption --1,600 rpm, Standard CR--

Both with and without EGR, fuel energy consumption rates (figure 16) were found to be approximately 20 pct lower at MBT timing compared to standard ignition timing; this was found with all fuel blends. Fuel consumption increased rapidly at the standard ignition timing/lean A/F combinations. As the A/F is leaned from near stoichiometric, the ignition timing must be advanced to maintain level power output at constant fuel rate. Therefore, maintaining standard spark timing while leaning the A/F would be expected as the data confirm, to adversely affect fuel economy. Fuel penalty was associated in the EGR at all spark-advance settings for all methanol/gasoline blends. However, using pure methanol, EGR adversely affected fuel economy only with the less-advanced firing schedules; which is to say that as spark timing was advanced using pure methanol the fuel economy sensitivity to EGR diminished and disappeared.

SUMMARY

Methanol/Gasoline--Vehicle and Simulated Cycle Tests

With respect to vehicles adjusted for gasoline fuel, the addition of 5 to 10 pct methanol to the gasoline resulted in increased unburned fuel emission, reduced CO emission, and reduced fuel energy economy; NO_x emissions were unchanged. Aldehyde and unburned methanol in the exhaust were typically increased by addition of methanol, but catalytic treatment of the exhaust selectively reduced those components with higher efficiency that was found for the accompanying CO and HC. Over a wide range of ambient temperatures, the emission data for methanol blends suggest that vapor-pressure effects from methanol addition can be significant and that, if methanol were used as a fuel component, it would be necessary that vapor-pressure characteristics of the base fuel be appropriately tailored. There is the parallel clear inference that addition of methanol in random distribution would be unsatisfactory.

Five test vehicles each using 10 pct methanol in gasoline were operated for approximately 7,500 miles. During the test period, emissions levels and fuel economy remained essentially stable, and none of the vehicles failed to operate because of fuel-related problems.

A vehicle was optimized for best fuel economy at a given level of NO_x control using each of four fuels--clear gasoline, and gasoline with 5, 10, and 15 pct methanol. Results showed that exhaust emissions and fuel energy economy were essentially unchanged between fuels.

Road-octane tests showed the blending octane value of methanol in methanol/gasoline mixtures to be dependent on the octane number of the base fuel. The BOV of methanol, based on road-octane rating, ranged from 114 for a 91 RON base fuel to 132 for an 84 RON base fuel. Additional road-octane tests at A/F from 13 to 7 showed no consistent trend of road-octane sensitivity to A/F; in general, however, the BOV of methanol tended to be lower at 13:1 A/F as compared with blending values found with leaner A/F adjustment.

Methanol and Methanol/Gasoline-- Engine Dynamometer Tests

Emissions and fuel economy were determined for an engine operated at steady-state conditions and using gasoline, methanol/gasoline blends, and pure methanol. Results suggested that with proper engine adjustments, up to 15 pct methanol could be used in gasoline without substantially affecting emissions or fuel economy. Devices and/or engine adjustments that influence emissions and fuel economy using gasoline have generally comparable influences using methanol/gasoline blends.

With pure methanol as fuel, CO and unburned fuel emissions levels either were lower or were equivalent to those measured when using methanol/gasoline; similarily compared, NO_x emissions were reduced by a factor of 2 to 3. Using pure methanol, an increase in compression ratio from the engine's standard 8.25:1 to 10.25:1 resulted in a 10 to 15 pct increase in fuel energy economy with only a minor increase in NO_x. The use of pure methanol may allow extension of the lean operating limit and increased engine CR to effect both low emissions and good fuel economy; requisite to use of pure methanol, however, is development of an adequate fuel-air management system.

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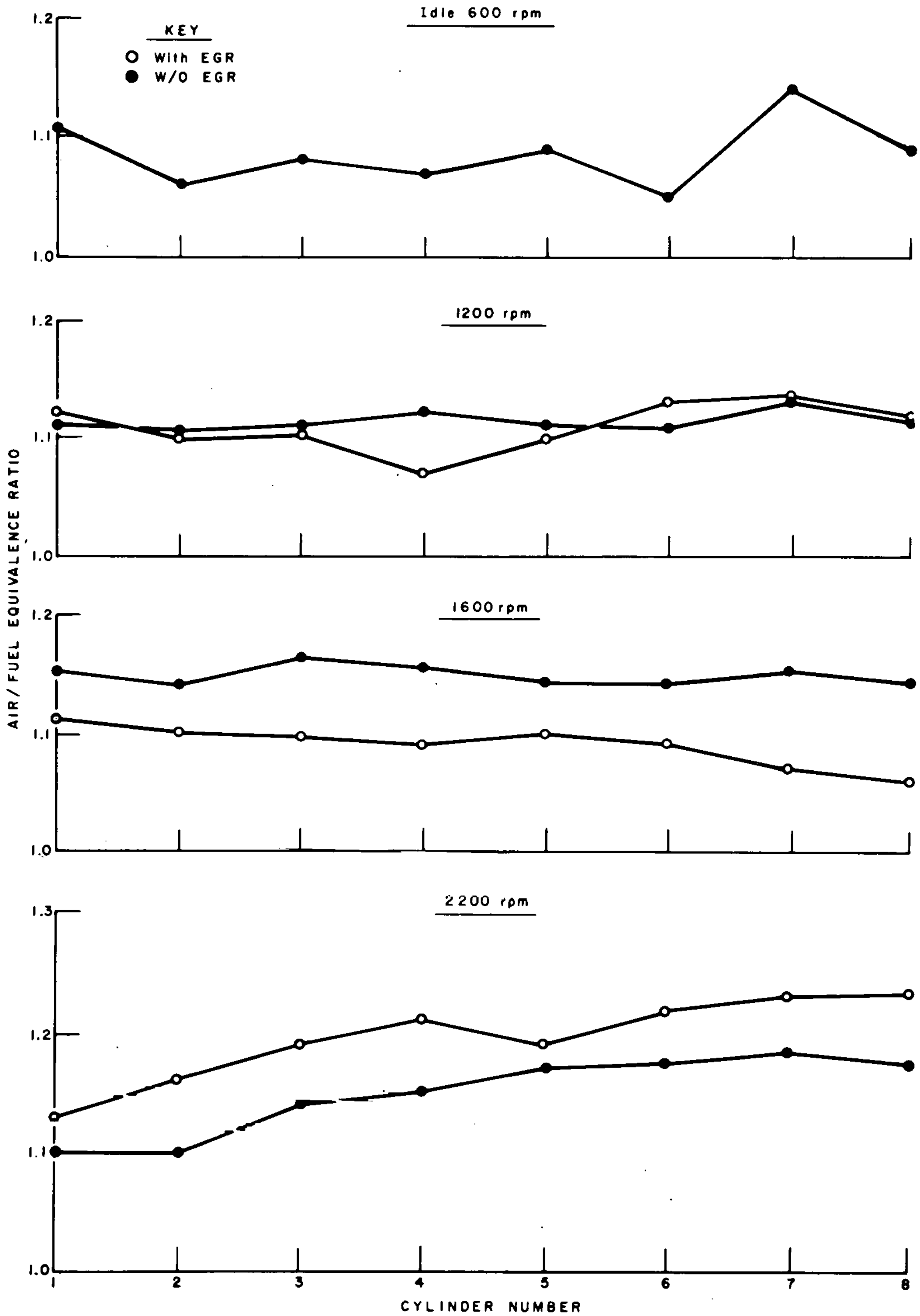

FIGURE A-1. - Mixture Distribution with Sonic-Flow Fuel Induction System--5% Methanol, standard CR

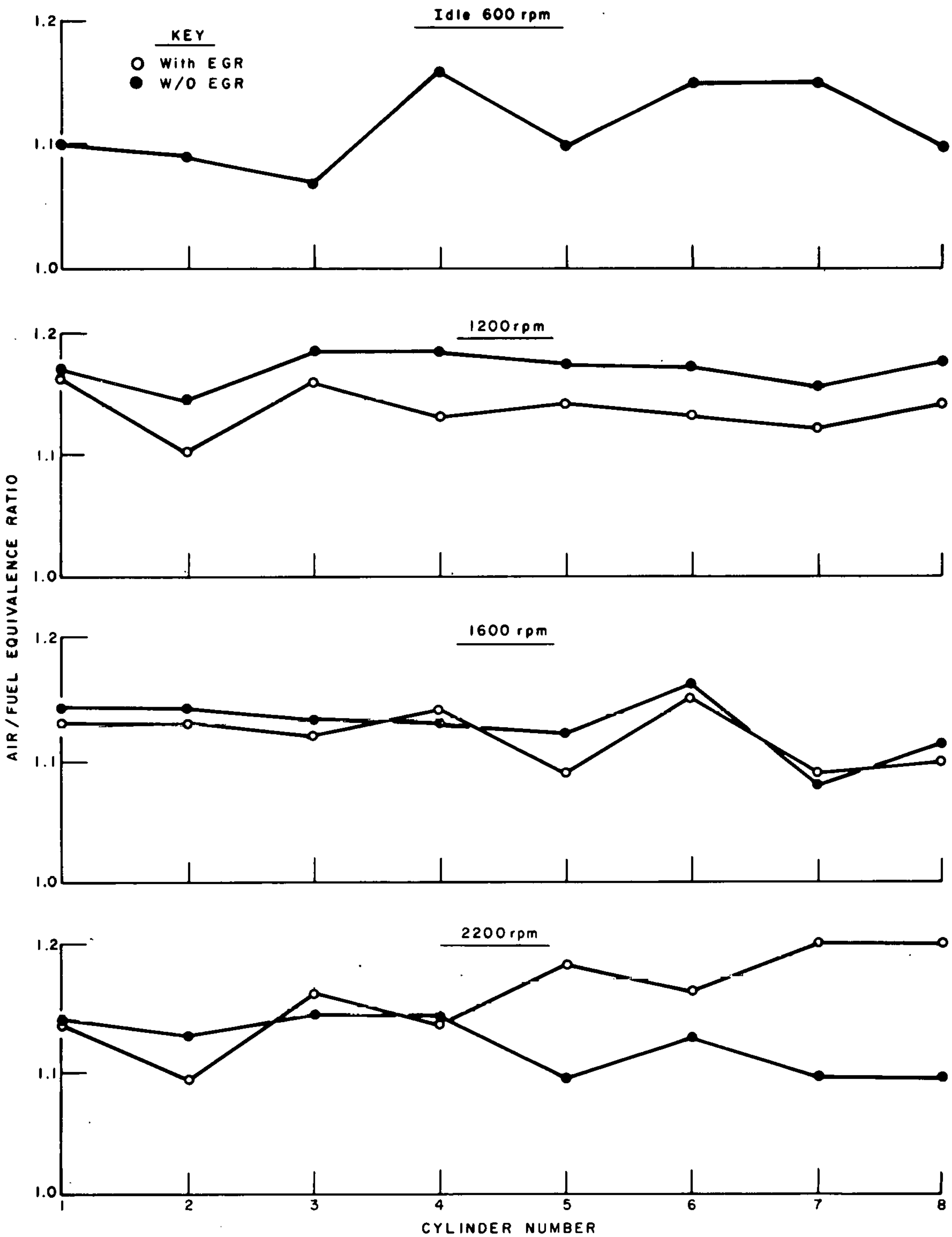

FIGURE A-2. - Mixture Distribution with Sonic-Flow Fuel Induction System--Pure Methanol, Standard CR

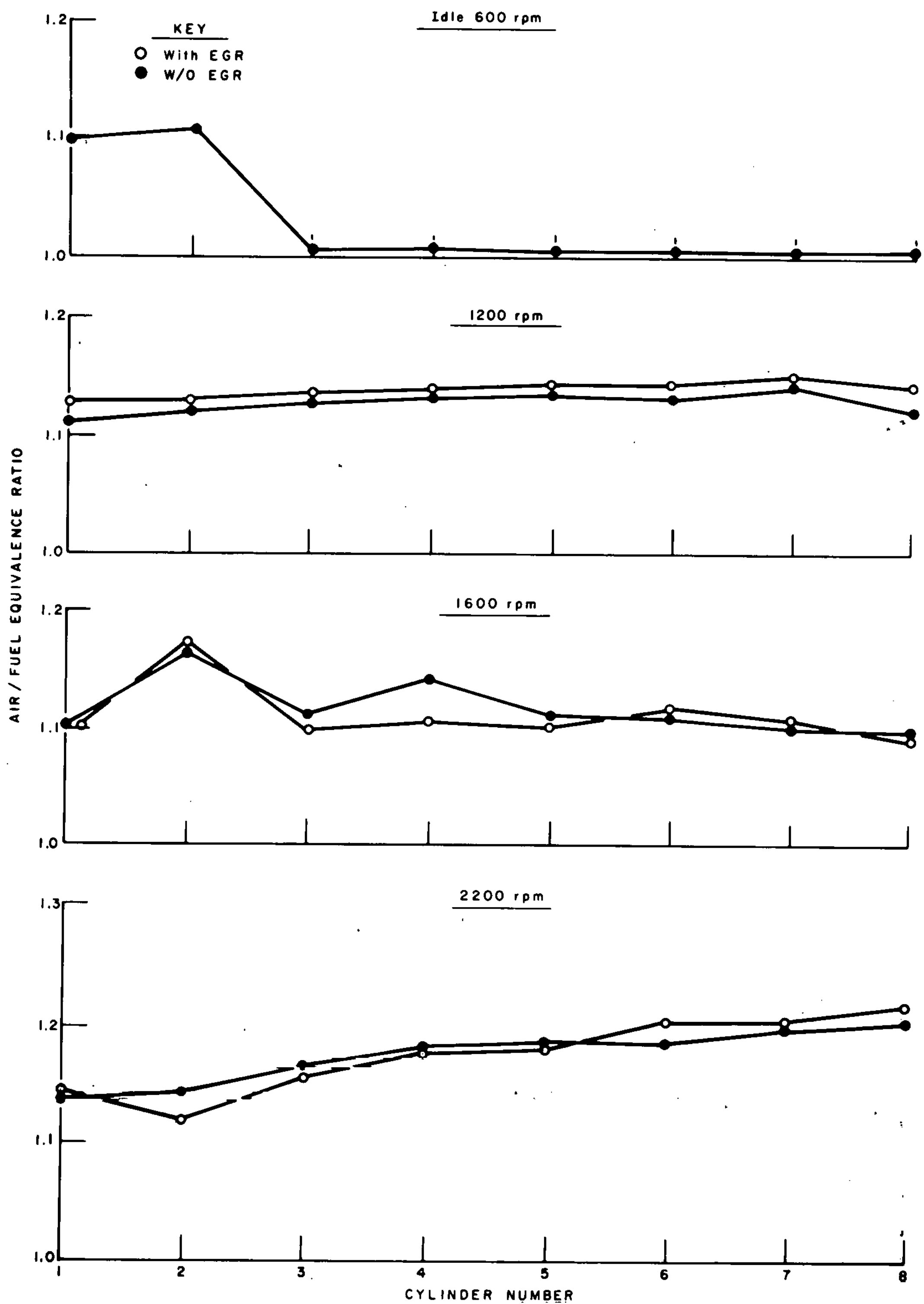

FIGURE A-3. - Mixture Distribution with Sonic-Flow Fuel Induction System--5% Methanol, 9.3 CR

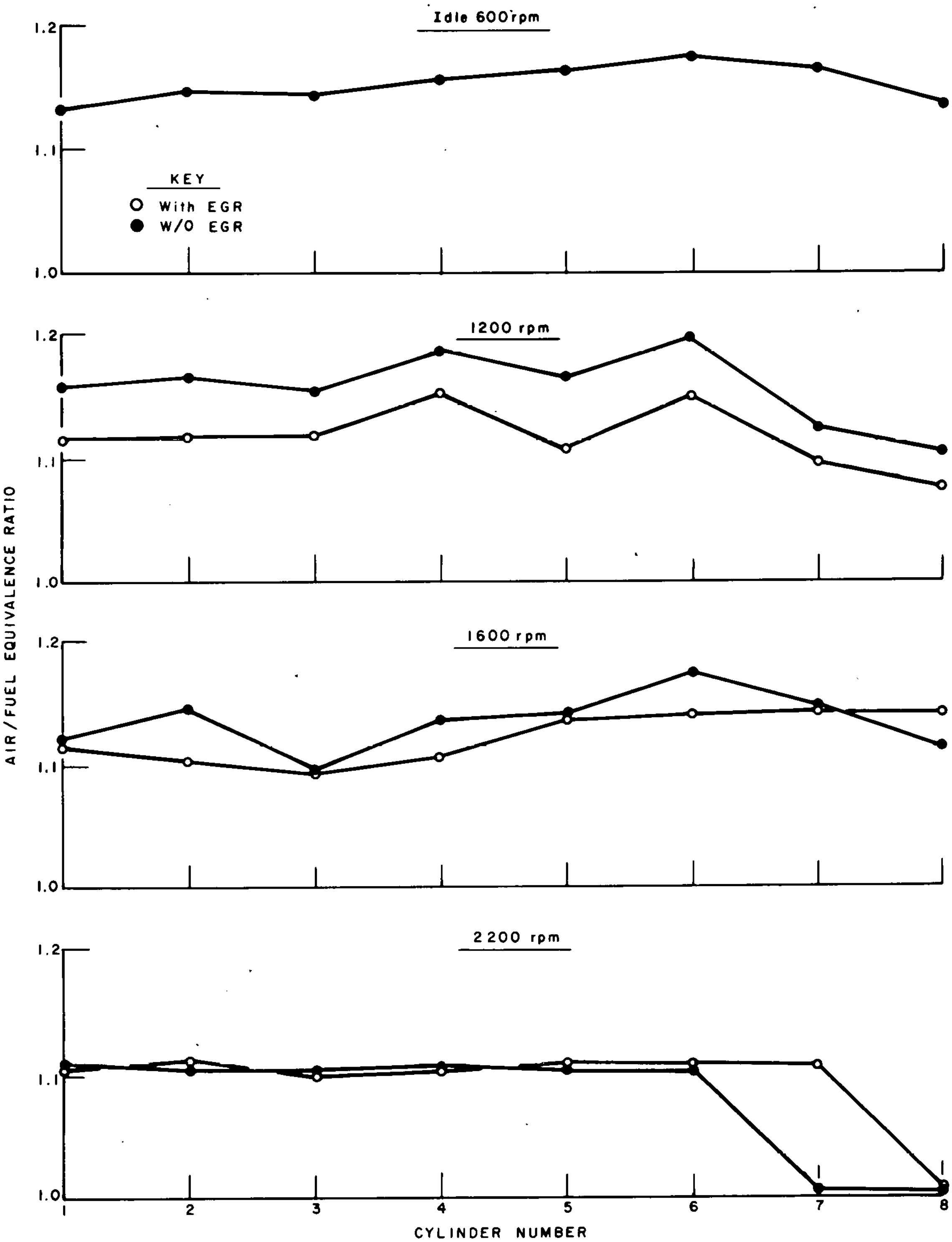

FIGURE A-4. - Mixture Distribution with Sonic-Flow Fuel Induction System--Pure Methanol, 9.3 CR

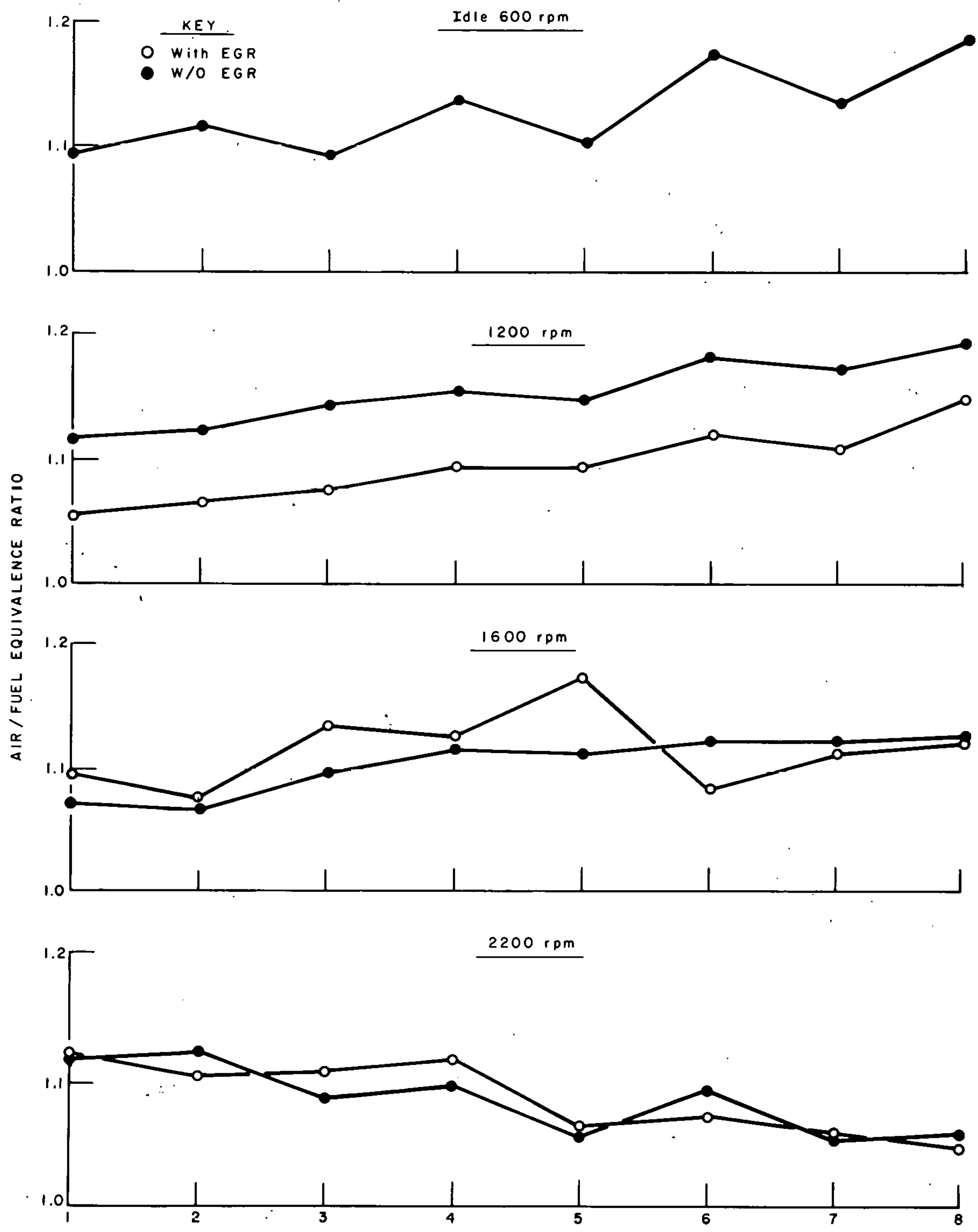

FIGURE A-5. - Mixture Distribution with Sonic-Flow Fuel Induction System--5% Methanol, 10 CR

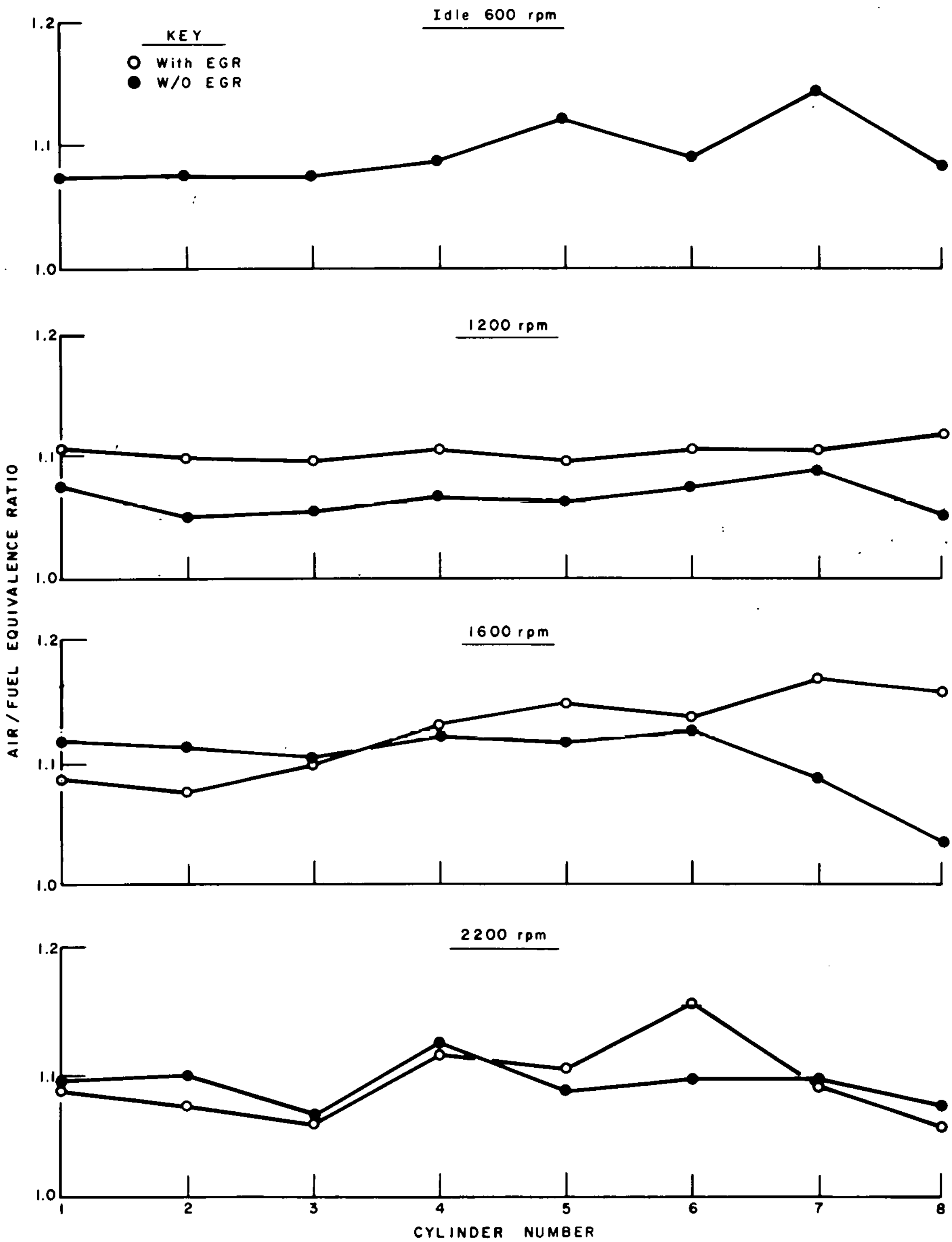

FIGURE A-6. - Mixture Distribution with Sonic-Flow Fuel Induction System--Pure Methanol, 10 CR

TABLE A-1. - Exhaust emissions and fuel rate --Vehicle A, commercial base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1.........	558.7	461.9	429.4	161.6	117.6	85.3	121.3	107.9	63.9
" 2.........	91.0	67.3	44.5	98.4	70.5	44.3	91.8	123.0	88.1
" 3.........	80.3	60.1	41.2	89.2	62.1	52.8	86.4	139.8	82.7
HC, Bag 1.........	30.1	21.7	24.4	7.7	8.1	10.6	8.7	14.7	11.2
" 2.........	5.7	7.1	9.2	5.7	7.1	7.4	7.0	7.1	8.3
" 3.........	5.0	7.2	7.4	5.1	9.9	9.6	6.6	9.7	10.6
NO_x, Bag 1.........	5.0	5.8	5.1	5.4	5.8	5.7	5.0	6.1	6.0
" 2.........	4.6	5.3	4.5	4.7	4.4	4.8	4.5	4.7	4.9
" 3.........	6.0	6.3	5.9	5.9	5.8	5.5	5.5	7.4	4.8
Aldehydes, Bag 1.........	0.77	0.85	0.85	0.60	0.44	0.65	0.62	0.69	0.72
" 2.........	.91	.91	1.20	.80	.86	.93	.90	.92	.97
" 3.........	.59	.64	.81	.48	.64	.53	.51	.47	.56
Methanol, Bag 1.........	0.13	0.72	0.64	0.11	0.33	0.70	0.14	0.56	0.77
" 2.........	.08	.35	.73	.09	.33	.58	.13	.37	.46
" 3.........	.06	.31	.51	.08	.93	1.05	.10	.99	1.91
COMPOSITE 1975 FTP, gram/mile									
CO......................	50.3	40.0	33.7	29.2	20.9	16.2	25.8	33.2	21.7
HC......................	2.9	2.7	3.2	1.6	2.2	2.3	1.9	2.5	2.4
NO_x......................	1.4	1.5	1.4	1.4	1.4	1.4	1.3	1.4	1.4
Aldehydes...............	.21	.22	.27	.18	.20	.21	.20	.20	.21
Methanol................	.02	.11	.17	.02	.13	.29	.03	.16	.20
FUEL ECONOMY, miles/gallon									
Emission cycle...........	8.5	8.2	7.8	9.1	9.2	8.4	9.5	8.5	8.6
Highway cycle............	16.9	15.7	15.2	15.3	15.2	14.1	16.1	14.5	14.7
FUEL ECONOMY, miles/10^5 btu									
Emission cycle...........	7.5	7.5	7.3	8.0	8.3	7.8	8.4	7.7	8.0
Highway cycle............	15.0	14.3	14.2	13.6	13.9	13.2	14.3	13.2	13.8

TABLE A-2. - Exhaust emissions and fuel rate --Vehicle A, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel..........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1.........	747.0	527.0	508.0	186.0	128.0	100.0	126.7	131.0	149.2
" 2.........	105.3	58.9	43.2	94.7	69.7	44.4	135.5	194.8	271.6
" 3.........	46.1	51.2	36.1	98.8	89.9	73.4	170.0	217.4	219.5
HC, Bag 1.........	32.4	23.8	19.2	10.8	10.2	9.3	8.1	7.9	8.1
" 2.........	3.5	5.1	6.4	6.4	8.6	10.0	4.3	4.0	4.1
" 3.........	4.9	5.8	7.0	6.2	9.0	10.3	7.3	8.4	10.5
NO_x, Bag 1.........	6.1	7.3	6.8	6.2	6.6	7.3	5.7	5.1	6.1
" 2.........	5.0	5.5	4.6	5.5	5.7	5.7	4.5	3.9	4.0
" 3.........	7.6	7.3	6.6	6.4	6.6	6.8	4.9	4.6	4.6
Aldehydes, Bag 1.........	0.70	0.66	0.83	0.74	0.78	0.93	0.57	0.58	0.64
" 2.........	.65	.78	1.08	.94	1.14	1.44	.66	.66	.70
" 3.........	.43	.47	.62	.58	.70	.85	.49	.47	.50
Methanol, Bag 1.........	0.08	0.49	0.76	0.11	0.27	0.49	0.13	0.29	0.60
" 2.........	.07	.23	.52	.06	.37	.66	.11	.25	.45
" 3.........	.05	.29	.50	.05	.81	1.94	.13	.87	1.93
COMPOSITE 1975 FTP, gram/mile									
CO......................	60.4	42.0	37.6	30.8	22.3	17.2	38.2	50.0	61.5
HC......................	2.7	2.5	2.5	2.0	2.3	2.6	1.6	1.6	1.8
NO_x......................	1.6	1.7	1.5	1.6	1.6	1.7	1.3	1.2	1.2
Aldehydes...............	.16	.18	.24	.21	.24	.31	.16	.16	.17
Methanol................	.02	.08	.15	.02	.13	.27	.03	.12	.24
FUEL ECONOMY, miles/gallon									
Emission cycle...........	8.3	8.4	8.4	8.6	8.8	8.4	9.0	8.9	8.8
Highway cycle............	14.6	14.9	15.6	15.0	15.1	14.7	15.5	16.2	15.9
FUEL ECONOMY, miles/10^5 btu									
Emission cycle...........	7.2	7.5	7.7	7.6	7.8	7.7	7.8	7.9	8.0
Highway cycle............	12.6	13.2	14.3	13.0	13.5	13.4	13.4	14.4	14.9

TABLE A-3. - Exhaust emissions and fuel rate --Vehicle B, Commercial base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1..........	1122.0	1125.0	1008.0	199.0	125.0	43.9	133.0	111.0	80.6
" 2..........	70.2	34.5	19.3	54.6	31.0	15.9	49.7	65.6	27.2
" 3..........	35.1	22.9	20.0	60.9	45.5	36.8	71.0	130	84.6
HC, Bag 1..........	43.8	48.2	51.1	10.3	9.6	11.0	9.4	9.2	14.9
" 2..........	4.5	4.6	3.9	5.4	5.5	4.5	5.2	6.1	4.9
" 3..........	5.3	5.6	8.0	7.0	11.0	11.5	8.7	10.9	12.3
NO_x, Bag 1..........	3.1	2.9	4.0	7.4	7.6	7.1	5.6	5.5	6.7
" 2..........	6.3	6.0	4.8	6.6	5.6	4.8	6.5	6.0	5.6
" 3..........	7.1	6.9	5.8	6.9	6.8	6.2	6.8	6.5	6.4
Aldehydes, Bag 1..........	0.47	0.45	0.64	0.37	0.30	0.49	0.34	0.46	0.57
" 2..........	.25	.47	.72	.45	.45	.58	.38	.49	.54
" 3..........	.40	.40	.61	.32	.39	.52	.33	.42	.45
Methanol, Bag 1..........	0.11	0.97	3.1	0.15	0.35	0.70	0.16	0.41	0.86
" 2..........	.09	.25	.42	.11	.20	.46	.13	.29	.37
" 3..........	.08	.19	.64	.16	1.08	1.43	.14	.92	2.28
COMPOSITE 1975 FTP, gram/mile									
CO........................	76.4	70.8	61.9	23.3	14.7	7.4	19.7	25.0	14.7
HC........................	3.6	3.8	4.1	1.8	2.1	2.1	1.9	2.2	2.4
NO_x........................	1.6	1.5	1.3	1.3	1.7	1.5	1.7	1.6	1.6
Aldehydes.................	.09	.12	.18	.11	.11	.15	.10	.12	.14
Methanol..................	.02	.10	.28	.04	.13	.22	.04	.19	.27
FUEL ECONOMY, miles/gallon									
Emission cycle............	9.1	8.6	8.1	10.5	10.6	9.6	11.0	10.3	10.2
Highway cycle.............	16.9	16.4	14.9	16.7	17.0	15.2	17.6	16.4	16.1
FUEL ECONOMY, miles/10^5 btu									
Emission cycle............	8.1	7.8	7.6	9.3	9.7	9.0	9.8	9.4	9.5
Highway cycle.............	15.0	14.9	13.9	14.8	15.5	14.2	15.6	14.9	15.0

TABLE A-4. - Exhaust emissions and fuel rate

--Vehicle B, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1..........	1370.0	1190.0	1269.0	169.0	101.0	79.9	113.0	115.0	68.0
" 2..........	59.5	25.6	19.7	33.6	21.4	14.9	78.2	177.0	97.0
" 3..........	35.3	20.0	18.9	49.5	40.1	37.2	105.0	212.0	151.0
HC, Bag 1..........	57.3	43.1	35.4	12.0	9.3	10.2	8.2	10.4	10.6
" 2..........	5.0	3.7	3.4	4.3	4.2	3.5	7.6	6.0	4.4
" 3..........	6.8	8.9	10.2	8.7	6.1	16.0	10.5	13.5	14.0
NO_x, Bag 1..........	3.2	2.9	4.2	10.2	8.5	8.2	6.4	6.9	7.7
" 2..........	7.0	5.5	3.9	7.4	6.3	5.0	6.6	5.8	6.8
" 3..........	8.7	6.7	5.4	8.5	7.5	7.0	6.9	6.5	7.3
Aldehydes, Bag 1..........	0.42	0.42	0.43	0.43	0.56	0.59	0.38	0.45	0.49
" 2..........	.48	.57	.77	.49	.66	.66	.35	.37	.44
" 3..........	.42	.53	.68	.43	.53	.56	.35	.29	.36
Methanol, Bag 1..........	0.08	0.92	1.49	0.13	0.32	0.60	0.17	0.41	0.65
" 2..........	.07	.24	.31	.10	.20	.32	.14	.41	.54
" 3..........	.07	.55	1.24	.09	.95	2.29	.15	.99	1.91
COMPOSITE 1975 FTP, gram/mile									
CO......................	87.8	73.2	76.8	18.1	11.7	9.30	24.9	45.8	28.3
HC......................	4.5	3.7	3.4	1.9	1.5	2.3	2.2	2.4	2.3
NO_x....................	1.8	1.4	1.2	2.2	1.9	1.7	1.8	1.7	1.9
Aldehydes...............	.12	.14	.18	.12	.16	.16	.10	.10	.11
Methanol................	.02	.13	.22	.03	.12	.25	.04	.15	.25
FUEL ECONOMY, miles/gallon									
Emission cycle...........	8.7	8.8	9.0	10.7	10.4	10.3	11.4	10.6	10.6
Highway cycle............	15.8	15.0	15.9	16.3	16.8	16.9	17.6	16.5	17.5
FUEL ECONOMY, miles/10^5 btu									
Emission cycle...........	7.5	7.8	8.2	9.3	9.2	9.4	9.9	9.4	9.7
Highway cycle............	13.7	13.3	14.5	14.1	14.9	15.4	15.2	14.7	16.0

TABLE A-5. - Exhaust emissions and fuel rate --Vehicle C, commercial base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel..........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1	430.1	355.5	343.8	150.7	98.5	81.0	119.5	95.3	68.6
" 2.........	56.2	26.0	16.1	41.8	18.7	14.3	67.2	109.9	62.7
" 3.........	65.8	39.2	27.5	76.5	62.3	47.1	102.2	161.9	104.2
HC, Bag 1.........	23.2	17.5	23.1	5.8	5.8	5.8	5.4	4.7	6.2
" 2.........	5.9	6.0	6.7	6.0	5.6	5.8	6.3	5.7	7.3
" 3.........	3.8	4.7	4.9	4.4	6.2	5.9	4.9	5.8	7.4
NO_x, Bag 1.........	9.8	11.3	12.3	8.8	9.9	8.9	7.9	7.2	9.6
" 2.........	13.6	13.2	15.4	9.6	10.3	7.9	11.7	7.5	10.9
" 3.........	9.7	9.7	10.1	8.2	9.2	8.0	8.3	6.2	7.3
Aldehydes, Bag 1.........	0.68	0.79	0.65	0.55	0.46	0.51	0.51	0.44	0.59
" 2.........	.85	.72	.89	.81	.77	.86	.74	.77	.90
" 3.........	.44	.72	.45	.49	.47	.52	.48	.44	.49
Methanol Bag 1.........	0.09	0.40	0.57	0.07	0.20	0.26	0.07	0.15	0.32
" 2.........	.08	.28	.45	.10	.24	.40	.10	.21	.40
" 3.........	.04	.27	.41	.06	.48	.92	.07	.20	.66
COMPOSITE 1975 FTP, gram/mile									
CO......................	37.2	41.9	24.0	20.2	12.9	10.1	23.6	32.4	20.2
HC......................	2.4	2.2	2.6	1.5	1.6	1.6	1.5	1.5	1.9
NO_x......................	3.1	3.1	3.5	2.4	2.6	2.2	2.6	1.9	2.6
Aldehydes.................	.19	.20	.19	.18	.17	.18	.16	.16	.19
Methanol..................	.02	.08	.12	.02	.08	.14	.02	.05	.12
FUEL ECONOMY, miles/gallon									
Emission cycle...........	11.1	10.3	9.8	11.8	11.4	11.2	11.9	11.9	10.8
Highway cycle............	20.2	17.2	16.8	16.5	15.6	15.2	17.7	17.8	16.3
FUEL ECONOMY, miles/10^5 btu									
Emission cycle...........	9.8	9.4	9.2	10.5	10.4	10.4	10.6	10.8	10.1
Highway cycle............	17.9	15.7	15.6	14.7	14.2	14.2	15.7	16.2	15.2

TABLE A-6. - Exhaust emissions and fuel rate --Vehicle C, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1.........	363.3	330.1	292.3	103.2	79.8	68.5	79.6	77.0	50.7
" 2.........	42.7	28.6	15.5	28.9	18.4	8.4	46.9	143.7	66.6
" 3.........	43.2	38.2	23.9	55.2	53.0	42.4	89.0	173.3	116.7
HC, Bag 1.........	13.8	20.4	22.1	6.5	6.2	7.7	5.2	5.7	5.8
" 2.........	7.5	6.9	7.2	5.8	5.5	6.0	5.5	5.9	6.1
" 3.........	4.4	5.2	6.5	5.2	5.8	6.2	4.8	5.5	6.0
NO_x Bag 1.........	11.8	11.1	12.7	11.7	11.0	12.0	10.2	10.6	10.8
" 2.........	19.2	16.1	15.9	13.2	11.2	10.6	13.9	7.5	10.9
" 3.........	12.4	10.5	9.5	10.1	9.9	10.0	8.3	6.1	7.9
Aldehydes, Bag 1.........	0.50	0.60	0.71	0.51	0.62	0.57	1.32	0.48	0.47
" 2.........	.48	.87	.98	.77	.92	.73	.44	.80	.67
" 3.........	.41	.43	.52	.46	.49	.55	.41	.44	.39
Methanol, Bag 1.........	0.07	0.34	0.74	0.06	0.28	0.33	0.05	0.20	0.38
" 2.........	.09	.24	.45	.06	.23	.42	.08	.25	.40
" 3.........	.05	.26	.44	.05	.40	.86	.05	.23	.65
COMPOSITE 1975 FTP, gram/mile									
CO.......................	30.2	25.7	20.7	14.0	11.1	8.3	17.6	36.8	20.7
HC.......................	2.4	2.9	2.7	1.5	1.5	1.7	1.4	1.5	1.6
NO_x.......................	3.7	3.9	3.6	3.2	2.9	2.9	3.8	2.1	2.9
Aldehydes.................	.13	.18	.21	.17	.20	.17	.17	.17	.15
Methanol.................	.02	.07	.14	.02	.07	.14	.01	.06	.13
FUEL ECONOMY, miles/gallon									
Emission cycle...........	10.7	10.6	9.6	12.3	11.3	11.4	12.7	11.4	11.4
Highway cycle............	18.2	17.8	16.1	19.0	17.5	16.5	19.3	17.3	16.6
FUEL ECONOMY, miles/10^5 btu									
Emission cycle...........	9.3	9.4	8.8	10.7	10.0	10.4	11.0	10.1	10.4
Highway cycle............	15.8	15.9	14.7	16.5	15.6	15.1	16.7	15.4	15.2

TABLE A-7. - Exhaust emissions and fuel rate

--Vehicle D, Commercial base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel............	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1..........	395.2	367.8	276.6	127.1	142.4	106.5	154.8	99.7	64.4
" 2..........	38.0	18.4	13.6	14.3	13.8	10.0	64.8	167.9	150.0
" 3..........	41.3	34.4	22.0	49.6	57.5	51.3	101.9	243.2	199.2
HC, Bag 1..........	28.9	31.5	31.5	12.4	16.3	13.2	12.9	9.6	9.6
" 2..........	2.2	.9	.8	1.3	1.3	1.1	6.8	14.5	14.7
" 3..........	1.7	3.0	3.2	5.4	8.9	10.5	8.7	19.8	22.1
NO_x, Bag 1..........	6.5	6.8	7.8	7.0	6.3	6.4	5.6	6.0	6.4
" 2..........	6.0	6.2	7.2	6.7	5.7	5.0	4.8	3.3	3.3
" 3..........	7.0	7.2	8.0	6.4	5.6	5.8	5.1	4.6	4.2
Aldehydes, Bag 1..........	0.15	0.17	0.18	0.15	0.20	0.18	0.15	0.14	0.18
" 2..........	.04	.03	.03	.03	.01	.08	.03	.05	.05
" 3..........	.03	.03	.03	.07	.06	.14	.09	.54	.82
Methanol, Bag 1..........	0.06	1.32	1.75	0.07	0.31	0.51	0.06	0.25	0.52
" 2..........	.01	.06	.07	.01	.03	.04	.02	.29	.46
" 3..........	.01	.22	.30	.01	.19	.44	.03	.65	1.36
COMPOSITE 1975 FTP, gram/mile									
CO........................	30.9	26.2	19.3	13.0	14.4	11.3	25.3	46.6	38.8
HC........................	2.1	2.2	2.2	1.3	1.8	1.7	2.3	4.0	4.2
NO_x........................	.1	1.8	2.0	1.8	1.5	1.5	1.4	1.1	1.1
Aldehydes.................	.01	.02	.02	.02	.02	.03	.02	.06	.08
Methanol..................	.01	.10	.07	.01	.04	.07	.01	.10	.20
FUEL ECONOMY, miles/gallon									
Emission cycle............	14.4	13.1	11.9	14.6	13.1	13.4	14.9	14.2	13.3
Highway cycle.............	23.0	21.0	19.3	21.6	18.6	18.6	22.2	22.7	21.0
FUEL ECONOMY, miles/10^5 btu									
Emission cycle............	12.8	11.9	11.1	13.0	11.9	12.6	13.2	12.9	12.4
Highway cycle.............	20.4	19.1	18.0	19.2	16.9	17.4	19.7	20.6	19.6

TABLE A-8. - Exhaust emissions and fuel rate --Vehicle D, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1.........	389.8	367.1	258.0	169.7	165.6	119.7	156.9	129.8	104.1
" 2.........	19.2	22.5	14.0	35.1	39.3	28.8	111.4	323.8	222.1
" 3.........	51.0	36.8	24.2	60.9	98.9	77.6	136.5	323.3	250.6
HC, Bag 1.........	42.7	42.8	26.7	10.7	17.5	12.5	10.2	8.4	9.6
" 2.........	1.2	1.1	0.8	2.0	3.2	1.7	7.3	14.5	11.8
" 3.........	1.9	3.5	3.0	3.5	10.5	9.8	7.3	17.8	20.1
NO_x, Bag 1.........	7.0	7.3	6.4	6.5	5.6	6.0	7.1	6.5	6.9
" 2.........	7.7	7.5	7.2	5.0	4.6	5.2	4.9	2.9	3.8
" 3.........	7.5	7.4	7.0	6.0	5.0	5.3	6.2	4.3	5.1
Aldehydes, Bag 1.........	0.19	0.18	0.18	0.11	0.11	0.18	0.11	0.10	0.11
" 2.........	.02	.02	.03	.01	.01	.01	.02	.20	.02
" 3.........	.02	.02	.04	.01	.10	.05	.05	.17	.22
Methanol, Bag 1.........	0.19	1.42	1.62	0.04	0.32	0.54	0.05	0.20	0.44
" 2.........	.01	.10	.11	.01	.13	.06	.02	.45	.46
" 3.........	.01	.20	.20	.01	.36	.44	.04	.85	1.15
COMPOSITE 1975 FTP, gram/mile									
CO.......................	23.8	26.8	18.5	19.0	22.2	16.6	34.2	75.2	54.6
HC.......................	2.8	2.9	1.9	1.2	2.2	1.7	2.1	3.8	3.7
NO_x.......................	2.0	2.0	1.9	1.5	1.3	1.5	1.6	1.1	1.3
Aldehydes.................	.02	.01	.02	.01	.02	.02	.01	.05	.03
Methanol..................	.01	.11	.12	.01	.06	.07	.01	.14	.17
FUEL ECONOMY, miles/gallon									
Emission cycle...........	13.2	12.5	12.1	15.1	14.5	13.6	15.2	12.9	13.1
Highway cycle............	22.4	21.2	18.7	22.8	22.5	20.2	24.6	22.1	21.0
FUEL ECONOMY, miles/10^5 btu									
Emission cycle...........	11.5	11.2	11.1	13.1	12.9	12.5	12.9	11.5	12.0
Highway cycle............	19.4	18.8	17.0	19.8	20.0	18.5	21.4	19.6	19.1

TABLE A-9. - Exhaust emissions and fuel rate --Vehicle E, commercial base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1.........	590.1	525.2	364.7	61.7	40.2	41.5	38.6	21.4	22.4
" 2.........	81.1	12.0	2.2	26.1	1.3	1.0	5.7	2.1	1.4
" 3.........	25.1	8.4	2.4	12.2	5.5	4.4	19.0	16.1	13.6
HC, Bag 1.........	22.3	23.9	14.9	4.2	4.7	8.1	4.6	4.4	5.5
" 2.........	1.5	.7	.8	.6	.4	.7	.4	.6	.7
" 3.........	.7	.6	.6	.7	.6	.8	.8	2.9	1.4
NO_x, Bag 1.........	8.4	7.7	7.6	8.9	8.5	8.6	7.8	8.2	7.3
" 2.........	4.4	4.6	5.8	4.2	5.3	5.9	4.7	5.6	5.3
" 3.........	7.3	7.1	7.3	6.4	6.8	6.8	7.3	7.3	6.8
Aldehydes, Bag 1.........	0.22	0.23	0.61	0.14	0.14	0.22	0.19	0.17	0.19
" 2.........	.02	.03	.48	.01	.03	.03	.01	.01	.02
" 3.........	.02	.02	.38	.01	.02	.02	.01	.03	.04
Methanol, Bag 1.........	0.09	0.43	0.77	0.06	0.13	0.37	0.08	0.17	0.27
" 2.........	.02	.02	.02	.01	.01	.01	.01	.01	.01
" 3.........	.01	.01	.01	.01	.01	.04	.01	.12	.27
COMPOSITE 1975 FTP, gram/mile									
CO........................	46.6	32.4	21.4	8.0	2.9	2.9	4.4	2.7	2.5
HC........................	1.5	1.5	1.0	.4	.4	.6	.4	.6	.7
NO_x......................	1.6	1.6	1.8	1.6	1.7	1.8	1.6	1.8	1.7
Aldehydes.................	.02	.02	.13	.01	.01	.02	.01	.01	.02
Methanol..................	.01	.03	.05	.01	.01	.02	.01	.02	.04
FUEL ECONOMY, miles/gallon									
Emission cycle............	10.2	9.4	8.8	10.8	9.2	9.1	10.9	9.9	9.7
Highway cycle.............	17.8	16.8	15.2	19.4	17.2	16.5	19.2	17.2	16.5
FUEL ECONOMY, miles/10^5 btu									
Emission cycle............	9.1	8.6	8.2	9.6	8.9	8.4	9.7	9.0	9.0
Highway cycle.............	15.8	15.3	14.2	17.3	15.6	15.4	17.0	16.7	15.4

TABLE A-10. - Exhaust emissions and fuel rate

--Vehicle E, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
	INDIVIDUAL BAG EMISSIONS, gram/test								
CO, Bag 1.........	429.1	455.7	361.3	50.1	56.6	45.5	59.9	34.1	24.4
" 2.........	49.1	5.7	1.9	16.7	1.3	.5	29.6	37.1	8.8
" 3.........	25.8	9.1	3.0	17.6	6.1	7.3	55.2	72.3	43.3
HC, Bag 1.........	20.9	21.5	18.0	4.3	8.1	8.7	4.8	5.5	11.2
" 2.........	.6	.4	.6	.6	.5	.7	.9	.8	.6
" 3.........	.6	.5	.6	.9	.7	1.0	2.0	3.9	4.6
NO_x, Bag 1.........	7.6	7.1	6.7	8.1	7.6	7.4	6.4	7.5	7.4
" 2.........	4.7	5.7	5.6	4.5	5.5	5.6	2.7	2.7	4.5
" 3.........	7.3	6.8	6.6	6.7	7.1	6.6	4.6	4.3	5.3
Aldehydes, Bag 1.........	0.16	0.15	0.23	0.10	0.17	0.17	0.14	0.16	0.10
" 2.........	.01	.01	.05	.01	.01	.02	.03	.01	.01
" 3.........	.01	.01	.04	.01	.01	.02	.01	.02	.04
Methanol, Bag 1.........	0.06	0.35	0.63	0.06	0.16	0.28	0.06	0.17	0.42
" 2.........	.01	.05	.01	.01	.01	.01	.01	.01	.01
" 3.........	.01	.01	.02	.01	.02	.03	.03	.23	.46
	COMPOSITE 1975 FTP, gram/mile								
CO......................	36.7	27.6	21.2	6.4	3.9	3.3	14.2	12.4	5.9
HC......................	1.3	1.3	1.1	.4	.6	.7	.5	.7	1.1
NO_x......................	1.6	1.7	1.6	1.6	1.7	1.7	1.1	1.1	1.4
Aldehydes................	.01	.01	.02	.01	.01	.01	.02	.01	.01
Methanol.................	.01	.02	.04	.01	.01	.02	.01	.03	.06
	FUEL ECONOMY, miles/gallon								
Emission cycle...........	9.2	8.8	8.5	10.6	10.0	9.3	10.9	10.5	9.7
Highway cycle............	18.0	17.5	16.6	18.8	17.3	17.1	17.5	16.8	16.1
	FUEL ECONOMY, miles/10^5 btu								
Emission cycle...........	8.0	7.1	7.8	9.2	8.9	8.5	9.4	9.3	8.9
Highway cycle............	15.6	15.6	15.2	16.3	15.4	15.6	15.2	14.9	14.7

TABLE A-11. - Exhaust emissions and fuel rate

--Vehicle F, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
	INDIVIDUAL BAG EMISSIONS, gram/test								
CO, Bag 1..........	1158.4	1090.4	892.0	66.5	50.4	49.2	38.4	28.2	31.5
" 2..........	35.5	23.2	18.6	28.8	17.1	15.1	36.4	50.7	33.0
" 3..........	26.3	18.1	21.5	22.9	41.2	27.9	44.8	94.2	75.2
HC, Bag 1..........	71.8	64.7	47.0	6.6	7.7	10.1	7.5	8.3	8.7
" 2..........	5.4	7.0	8.5	6.6	3.9	8.9	6.5	7.9	8.1
" 3..........	5.1	6.5	8.1	5.6	7.7	9.9	7.0	7.6	13.2
NO_x Bag 1..........	5.0	4.6	5.0	10.2	9.7	9.0	9.8	9.0	8.1
" 2..........	7.4	5.8	5.1	7.2	6.6	5.3	6.5	6.6	6.5
" 3..........	10.0	8.6	7.2	10.1	9.0	8.5	6.6	8.8	8.5
Aldehydes, Bag 1..........	1.07	0.94	0.98	0.81	0.84	0.98	0.67	0.65	0.76
" 2..........	.91	.91	1.16	.86	.87	1.10	.87	.96	.91
" 3..........	.62	.64	.70	.68	.69	.75	.60	.56	.72
Methanol, Bag 1..........	0.08	1.14	3.31	0.08	0.30	0.62	0.07	0.31	0.54
" 2..........	.07	.29	.57	.07	.33	.64	.08	.36	.62
" 3..........	.05	.26	.51	.05	.60	1.35	.06	.33	1.59
	COMPOSITE 1975 FTP, gram/mile								
CO......................	73.1	67.0	55.3	9.4	8.3	7.0	10.5	15.5	11.9
HC......................	5.2	5.1	4.5	1.7	1.4	2.5	1.8	2.1	2.6
NO_x......................	2.0	1.7	1.5	2.3	2.1	1.9	2.2	2.1	2.0
Aldehydes.................	.23	.22	.26	.21	.22	.26	.20	.21	.22
Methanol..................	.02	.12	.32	.02	.11	.22	.02	.09	.24
	FUEL ECONOMY, miles/gallon								
Emission cycle...........	9.3	9.2	9.1	10.8	10.3	9.7	11.4	11.1	11.1
Highway cycle............	15.7	15.8	16.7	16.7	16.1	14.9	15.7	16.8	16.3
	FUEL ECONOMY, miles/10^5 btu								
Emission cycle...........	8.3	8.5	9.6	9.6	9.4	9.1	10.1	10.1	10.3
Highway cycle............	13.9	14.7	14.8	14.8	14.7	13.2	13.9	15.2	15.3

TABLE A-12. - Exhaust emissions and fuel rate

--Vehicle G, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
	INDIVIDUAL BAG EMISSIONS, gram/test								
CO, Bag 1..........	271.9	256.8	242.3	109.5	96.1	94.3	48.9	48.9	52.7
" 2..........	20.2	19.2	30.1	19.0	22.1	25.8	19.9	42.7	30.2
" 3..........	19.3	18.7	22.8	23.6	29.4	25.9	28.3	59.9	42.8
HC, Bag 1..........	24.6	27.2	27.2	4.8	6.7	7.0	2.8	3.1	4.0
" 2..........	2.3	2.9	7.9	2.2	2.6	3.7	1.9	1.9	2.0
" 3..........	3.2	4.6	5.7	3.6	5.0	6.3	3.7	4.0	4.0
NO_x, Bag 1..........	15.9	15.5	13.2	7.3	7.5	7.0	7.2	6.7	6.6
" 2..........	7.7	7.0	6.2	6.9	7.1	6.5	7.3	7.9	7.3
" 3..........	7.2	6.1	5.9	7.4	7.7	6.8	7.8	7.5	7.3
Aldehydes, Bag 1..........	1.10	1.00	1.10	9.48	0.64	0.69	0.37	0.51	0.43
" 2..........	.42	.40	.92	.39	.39	.60	.33	.37	.37
" 3..........	.42	.46	.62	.33	.40	.54	.29	.32	.30
Methanol, Bag 1..........	0.06	0.04	0.03	0.05	0.19	0.38	0.04	0.16	0.25
" 2..........	.55	.12	.27	.04	.10	.25	.04	.10	.13
" 3..........	1.20	.46	.53	.03	.58	1.10	.04	.43	.87
	COMPOSITE 1975 FTP, gram/mile								
CO.......................	19.8	18.7	19.6	10.6	10.7	10.8	7.6	13.1	10.3
HC.......................	2.0	2.3	3.1	.8	1.1	1.4	.7	.7	.8
NO_x.......................	2.5	2.3	2.0	1.9	2.0	1.8	2.0	2.0	1.9
Aldehydes................	.15	.15	.23	.11	.12	.16	.09	.10	.10
Methanol.................	.01	.07	.17	.01	.07	.14	.01	.06	.09
	FUEL ECONOMY, miles/gallon								
Emission cycle...........	10.3	9.8	9.6	10.6	9.4	9.8	11.2	10.8	10.7
Highway cycle............	16.3	15.1	14.5	16.8	14.7	15.0	17.2	16.3	16.4
	FUEL ECONOMY, miles/10^5 btu								
Emission cycle...........	9.2	8.9	9.0	9.4	8.6	9.1	9.9	9.8	10.0
Highway cycle............	14.4	13.7	13.5	14.9	13.4	14.0	15.3	14.8	15.3

TABLE A-13. - Exhaust emissions and fuel rate --Vehicle H, Indolene base fuel/methanol blends--

Ambient temperature, °F...		20			75			100	
Methanol concentration in base fuel...........		Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test										
CO,	Bag 1..........	308.0	244.0	246.0	73.9	68.2	53.6	18.5	24.7	17.6
	" 2..........	.3	.3	.3	.2	.3	.3	.3	.3	.2
	" 3..........	.4	.5	.5	2.0	2.9	1.8	1.0	2.5	3.7
HC,	Bag 1..........	17.5	20.0	25.7	4.6	6.0	6.0	4.9	8.3	4.9
	" 2..........	.6	1.2	1.4	.6	1.0	1.8	.5	.5	.7
	" 3..........	.8	.9	1.2	.8	3.0	2.4	.9	2.1	4.9
NO_x,	Bag 1..........	9.9	13.8	10.9	12.1	10.7	10.3	12.6	11.5	10.0
	" 2..........	7.0	7.8	3.9	8.6	8.0	6.4	8.0	7.0	5.8
	" 3..........	11.3	10.7	8.3	12.3	11.1	10.8	12.5	11.5	11.1
Aldehydes,	Bag 1..........	0.23	0.27	0.30	0.16	0.18	0.24	0.17	0.20	0.22
	" 2..........	.06	.03	.10	.03	.05	.09	.03	.04	.04
	" 3..........	.06	.07	.10	.04	.06	.09	.03	.05	.08
Methanol,	Bag 1..........	0.04	0.38	1.10	0.02	0.08	0.31	0.03	0.08	0.14
	" 2..........	.01	.03	.07	.01	.01	.02	.01	.02	.02
	" 3..........	.01	.01	.02	.01	.07	.05	.01	.10	.28
COMPOSITE 1975 FTP, gram/mile										
CO........................		17.7	14.0	14.2	4.4	4.2	3.3	1.6	1.6	1.3
HC........................		1.2	1.4	1.8	.4	.7	.8	.4	.7	.8
NO_x........................		2.4	2.7	1.8	2.8	2.5	2.3	2.8	2.5	2.2
Aldehydes.................		.03	.03	.04	.02	.02	.03	.02	.02	.02
Methanol..................		.01	.03	.07	.01	.01	.02	.01	.01	.03
FUEL ECONOMY, miles/gallon										
Emission cycle............		9.3	9.1	8.7	9.9	9.3	9.2	10.0	10.3	10.5
Highway cycle.............		15.3	15.1	14.0	16.2	15.3	14.0	15.7	16.5	16.0
FUEL ECONOMY, miles/10^5 btu										
Emission cycle............		8.2	8.3	8.1	8.8	8.4	8.6	8.7	8.6	9.0
Highway cycle.............		13.6	13.7	13.0	14.3	14.0	13.0	14.0	15.0	15.1

TABLE A-14. - Exhaust emissions and fuel rate

--Vehicle I, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel............	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1..........	325.2	277.0	290.1	118.5	56.4	130.6	40.4	30.2	24.8
" 2..........	.2	.2	.2	.2	.3	.8	.4	1.1	.9
" 3..........	1.3	1.1	1.6	3.0	1.2	4.8	3.2	19.5	9.9
HC, Bag 1..........	31.2	29.7	32.4	7.0	5.6	9.1	4.2	4.5	4.4
" 2..........	.7	.8	1.0	.7	.8	.8	.8	.7	.8
" 3..........	.8	.7	.9	.8	1.4	1.8	1.1	1.6	2.4
NO_x, Bag 1..........	6.1	6.6	7.2	7.4	7.8	8.1	6.5	7.3	6.6
" 2..........	8.3	8.2	8.4	8.9	7.8	8.9	6.0	5.3	5.8
" 3..........	8.0	7.9	8.6	7.4	7.1	7.0	3.8	2.6	3.0
Aldehydes, Bag 1..........	0.26	0.28	0.37	0.19	0.24	0.32	0.20	0.22	0.23
" 2..........	.02	.03	.06	.01	.02	.02	.01	.01	.01
" 3..........	.03	.04	.01	.01	.02	.01	.01	.01	.01
Methanol, Bag 1..........	0.08	0.50	0.87	0.05	0.17	0.38	0.05	0.13	0.16
" 2..........	.01	.01	.01	.01	.01	.01	.01	.01	.01
" 3..........	.01	.01	.01	.01	.01	.03	.02	.04	.10
COMPOSITE 1975 FTP, gram/mile									
CO........................	18.8	16.0	16.8	7.0	3.4	8.0	2.6	3.4	2.3
HC........................	1.9	1.9	2.1	.6	.6	.8	.4	.5	.5
NO_x........................	2.1	2.1	2.2	2.2	2.0	2.2	1.5	1.3	1.4
Aldehydes.................	.02	.02	.04	.01	.02	.02	.01	.02	.02
Methanol..................	.01	.03	.05	.01	.01	.02	.01	.01	.02
FUEL ECONOMY, miles/gallon									
Emission cycle............	13.5	13.5	12.8	14.7	14.3	14.5	15.2	13.6	14.4
Highway cycle.............	19.5	19.9	19.1	21.0	19.6	20.5	19.5	18.0	18.3
FUEL ECONOMY, miles/10^5 btu									
Emission cycle............	12.0	12.3	11.9	13.0	13.0	13.6	13.5	12.4	13.4
Highway cycle.............	17.3	18.1	17.9	18.6	17.9	19.1	17.3	16.4	17.1

TABLE A-15. - Exhaust emissions and fuel rate --Vehicle J, Indolene base fuel/methanol blends--

Ambient temperature, °F...	20			75			100		
Methanol concentration in base fuel...........	Clear	5%	10%	Clear	5%	10%	Clear	5%	10%
INDIVIDUAL BAG EMISSIONS, gram/test									
CO, Bag 1..........	470.7	442.9	350.4	80.1	64.2	94.4	76.0	54.0	47.1
" 2..........	26.2	23.7	25.2	20.0	19.7	17.9	25.5	22.6	21.5
" 3..........	27.4	25.9	26.5	35.1	35.1	31.7	41.4	49.9	38.4
HC, Bag 1..........	27.9	27.0	29.4	5.1	5.8	8.6	4.3	4.8	5.8
" 2..........	3.4	4.3	5.9	3.6	3.7	4.2	3.1	3.4	3.5
" 3..........	3.9	4.2	7.1	4.5	4.8	6.8	4.8	5.5	6.4
NO_x, Bag 1..........	13.6	14.4	14.4	8.3	7.9	7.7	8.2	7.9	7.7
" 2..........	7.5	6.3	6.0	9.2	7.5	6.7	9.7	10.9	8.0
" 3..........	7.7	7.1	6.8	8.1	8.0	8.0	10.0	9.9	8.7
Aldehydes, Bag 1..........	1.05	1.13	1.17	0.54	0.53	0.62	0.53	0.53	0.64
" 2..........	.68	1.03	.99	.66	.62	.68	.56	.58	.51
" 3..........	.54	.65	.82	.49	.58	.56	.51	.43	.55
Methanol, Bag 1..........	0.12	0.85	1.64	0.06	0.19	0.47	0.06	0.19	0.35
" 2..........	.05	.22	.39	.06	.15	.25	.06	.17	.27
" 3..........	.05	.22	.47	.06	.69	1.21	.06	.62	1.34
COMPOSITE 1975 FTP, gram/mile									
CO......................	32.6	30.5	25.5	9.9	9.0	10.2	10.9	9.9	8.5
HC......................	2.3	2.4	3.0	1.1	1.2	1.6	1.0	1.2	1.3
NO_x......................	2.4	2.2	2.1	2.3	2.1	1.9	2.5	2.7	2.2
Aldehydes................	.19	.25	.26	.16	.16	.17	.14	.14	.15
Methanol.................	.02	.09	.18	.02	.08	.15	.02	.08	.16
FUEL ECONOMY, miles/gallon									
Emission cycle...........	9.1	8.9	7.8	9.9	9.5	8.6	10.6	9.7	9.1
Highway cycle............	16.5	15.1	13.3	18.5	17.3	14.9	19.1	17.8	16.0
FUEL ECONOMY, miles/10^5 btu									
Emission cycle...........	8.1	8.1	7.3	8.8	8.6	8.1	9.4	8.8	8.5
Highway cycle............	14.7	13.7	12.4	16.4	15.7	13.9	16.9	16.2	14.9

TABLE A-16. - Exhaust emissions and fuel economy (5% methanol fuel blend--MBT timing, road load, and standard CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^6 BTU per hour	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hour				
1,200 RPM										
1.08	48	ON	14.1	1.83	10.1	51.2	85.6	75.3	5.9	14.6
1.18	48	ON	13.0	1.78	9.8	28.2	102.6	112.8	6.8	8.7
1.25	52	ON	12.3	1.76	9.7	19.8	110.4	155.6	9.0	12.1
1.09	40	OFF	16.6	1.61	8.9	100.8	44.6	36.3	8.7	10.5
1.20	44	OFF	15.8	1.61	8.9	63.9	50.8	35.7	5.3	9.6
1.29	48	OFF	14.7	1.65	9.1	44.6	66.3	47.7	9.3	7.4
1.37	48	OFF	13.2	1.80	9.9	20.5	95.2	93.9	10.9	10.9
1,600 RPM										
1.09	46	ON	14.8	2.36	13.0	71.0	99.5	41.2	3.8	3.8
1.19	52	ON	14.0	2.45	13.5	47.0	146.6	45.4	1.2	3.4
1.27	54	ON	12.9	2.58	14.2	37.4	192.8	193.2	3.4	10.1
1.09	42	OFF	16.8	2.27	12.5	175.1	78.5	41.8	3.8	3.4
1.20	48	OFF	16.0	2.28	12.6	105.0	90.7	33.6	1.3	2.9
1.29	52	OFF	15.1	2.34	12.9	69.3	126.0	42.0	4.2	3.4
1.35	52	OFF	13.4	2.45	13.5	53.3	167.2	202.4	8.4	14.7
2,200 RPM										
1.10	48	ON	13.4	3.63	20.0	274.9	136.9	35.4	3.5	4.1
1.18	52	ON	12.6	3.68	20.3	201.3	182.7	40.0	5.2	4.6
1.27	54	ON	10.7	3.90	21.5	155.8	339.3	321.3	11.6	22.6
1.10	42	OFF	14.2	3.65	20.1	422.2	135.1	28.4	3.5	3.5
1.21	48	OFF	13.2	3.65	20.1	342.8	161.8	32.5	4.6	3.5
1.28	52	OFF	12.3	3.79	20.9	243.6	237.8	42.3	6.4	4.6
1.37	52	OFF	10.5	3.94	21.7	216.3	390.9	313.8	18.6	29.6

TABLE A-17. - Exhaust emissions and fuel economy (10% methanol fuel blend--MBT timing, road load, and standard CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^6 BTU per hour	Fuel economy: lb/hr	NO_x (Gram/hour)	Before catalyst: CO (Gram/hour)	Before catalyst: HC (Gram/hour)	After catalyst: CO (Gram/hour)	After catalyst: HC (Gram/hour)
1,200 RPM										
1.08	48	ON	14.2	1.79	10.2	46.5	81.8	83.4	1.9	9.3
1.17	50	ON	13.2	1.78	10.1	40.0	103.2	156.9	2.2	11.8
1.26	52	ON	12.1	1.79	10.2	25.7	119.4	193.1	2.5	17.1
1.09	40	OFF	16.9	1.63	9.3	89.9	48.4	35.7	1.9	5.0
1.21	46	OFF	15.9	1.62	9.2	63.9	57.4	42.8	1.9	5.6
1.32	50	OFF	14.7	1.67	9.5	36.6	65.1	52.1	1.6	5.6
1.36	50	OFF	13.7	1.76	10.0	22.0	80.0	82.8	3.1	7.8
1,600 RPM										
1.09	48	ON	15.0	2.37	13.5	68.5	103.3	43.3	2.5	3.4
1.20	52	ON	14.0	2.41	13.7	45.4	136.5	50.4	2.1	4.2
1.26	54	ON	13.1	2.46	14.0	30.2	173.5	102.1	3.8	8.4
1.09	40	OFF	17.0	2.29	13.0	156.2	54.6	28.6	1.2	3.4
1.21	46	OFF	16.0	2.29	13.0	112.6	97.9	35.3	2.1	3.4
1.30	52	OFF	15.0	2.32	13.2	76.9	122.2	52.1	1.3	4.6
1.34	52	OFF	13.9	2.37	13.5	64.7	160.4	240.2	4.2	12.6
2,200 RPM										
1.09	48	ON	14.6	3.64	20.7	248.6	164.1	41.8	5.8	5.2
1.20	52	ON	12.6	3.67	20.9	188.5	203.0	38.9	6.4	3.5
1.25	54	ON	11.6	3.66	20.8	171.0	252.9	87.6	6.4	7.5
1.09	42	OFF	14.4	3.50	19.9	348.0	237.8	31.3	5.2	3.5
1.20	50	OFF	13.6	3.60	20.5	280.0	172.8	31.9	6.4	3.5
1.26	52	OFF	12.8	3.62	20.6	218.7	203.0	40.0	7.5	3.5
1.34	52	OFF	11.2	3.85	21.9	145.0	296.4	74.2	7.5	7.0

TABLE A-18. - Exhaust emissions and fuel economy (15% methanol fuel blend--MBT timing, road load, and standard CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^6 BTU per hour	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hour				
1,200 RPM										
1.07	48	ON	13.9	1.76	10.3	34.4	77.5	90.5	4.3	4.3
1.20	50	ON	12.9	1.76	10.3	27.3	107.3	140.1	4.3	13.3
1.26	54	ON	12.1	1.81	10.6	22.3	119.7	260.4	2.8	18.0
1.09	40	OFF	16.4	1.64	9.6	86.8	46.8	37.8	5.6	8.1
1.20	48	OFF	15.8	1.62	9.5	66.3	54.6	45.9	5.9	9.3
1.32	50	OFF	14.7	1.64	9.6	36.9	67.0	53.0	2.8	9.0
1.36	50	OFF	13.9	1.71	10.0	21.7	80.6	79.4	3.1	10.9
1,600 RPM										
1.09	48	ON	14.3	2.40	14.1	62.2	97.9	49.1	5.5	2.5
1.19	52	ON	13.8	2.39	14.0	44.1	138.2	60.1	12.6	9.7
1.27	54	ON	12.7	2.44	14.3	28.1	168.8	118.9	11.3	15.5
1.10	40	OFF	16.0	2.34	13.7	155.0	83.6	37.4	7.6	2.5
1.21	46	OFF	15.9	2.25	13.3	103.3	99.1	41.6	11.8	8.8
1.29	48	OFF	14.5	2.32	13.6	52.5	126.4	56.7	9.7	8.4
1.35	52	OFF	13.9	2.39	14.0	44.1	160.9	222.6	12.6	16.8
2,200 RPM										
1.09	48	ON	13.3	3.68	21.6	225.0	154.3	42.3	4.6	3.5
1.18	52	ON	12.3	3.73	21.9	174.0	185.0	37.7	5.2	3.5
1.28	52	ON	10.6	3.94	23.1	92.2	280.1	74.8	7.0	7.0
1.10	42	OFF	13.9	3.75	22.0	312.0	164.1	48.1	5.2	5.8
1.20	50	OFF	13.4	3.67	21.5	287.7	176.9	37.1	5.2	3.5
1.29	52	OFF	12.0	3.73	21.9	152.5	212.9	47.0	6.4	4.1
1.33	52	OFF	10.9	3.94	23.1	120.4	388.6	306.8	13.3	20.3

TABLE A-19. - Exhaust emissions and fuel economy (100% methanol fuel blend--MBT timing, road load, and standard CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum "Hg	Fuel economy 10^6 BTU per hour	Fuel economy lb/hr	NO_x	Before catalyst CO	Before catalyst HC	After catalyst CO	After catalyst HC
						Gram/hour				
1,200 RPM										
1.09	44	ON	14.9	1.75	20.4	7.1	51.2	57.0	6.2	7.4
1.19	50	ON	14.1	1.72	20.1	6.2	56.4	69.4	5.0	10.2
1.27	50	ON	14.0	1.83	21.3	5.0	77.8	103.2	1.9	4.0
1.36	50	ON	12.7	1.80	21.0	3.4	101.1	178.9	6.2	4.7
1.09	30	OFF	16.7	1.73	20.2	36.3	60.5	36.0	6.2	4.0
1.20	36	OFF	16.2	1.76	20.5	35.7	64.5	54.9	3.7	4.7
1.28	38	OFF	16.0	1.81	21.1	28.5	65.1	64.5	3.1	6.2
1.37	42	OFF	14.9	1.78	20.8	15.8	67.9	75.6	6.2	5.6
1,600 RPM										
1.09	40	ON	16.1	2.37	27.7	30.2	80.6	51.2	2.9	4.6
1.19	48	ON	15.8	2.39	27.9	23.1	76.4	71.8	4.6	9.2
1.26	50	ON	14.9	2.48	28.9	16.4	88.6	92.3	5.9	14.7
1.38	50	ON	14.2	2.37	27.7	9.2	114.2	147.4	6.7	5.9
1.09	30	OFF	17.2	2.41	28.2	59.6	94.1	31.1	3.8	8.0
1.19	36	OFF	16.7	2.38	28.9	59.6	92.0	47.5	4.6	8.4
1.29	40	OFF	16.3	2.28	26.7	31.9	79.0	60.5	5.9	5.0
1.41	44	OFF	15.4	2.32	27.0	13.6	89.0	97.9	7.6	5.9
2,200 RPM										
1.09	38	ON	14.2	3.87	45.1	78.3	153.7	49.3	7.5	44.1
1.18	48	ON	13.5	3.79	44.2	89.9	139.8	67.9	10.4	41.2
1.26	52	ON	12.9	3.80	44.3	54.5	128.8	93.4	11.0	31.3
1.34	54	ON	11.9	3.76	43.9	26.7	137.5	129.3	11.6	36.5
1.09	28	OFF	14.9	3.89	45.4	128.2	149.6	124.9	24.9	7.0
1.20	38	OFF	14.0	3.64	42.5	107.3	174.0	60.3	13.9	20.9
1.28	38	OFF	13.8	3.60	42.0	58.0	140.4	93.4	11.0	17.4
1.37	50	OFF	13.6	3.54	41.3	59.2	142.7	124.1	11.6	19.1

TABLE A-20. - Exhaust emissions and fuel economy (5% methanol fuel blend--MBT timing, road load, and 9.3 CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy		NO_x	Before catalyst		After catalyst	
				10^5 BTU per hr	lb/hr		CO	HC	CO	HC
						Gram/hr				
1,200 RPM										
1.07	48	ON	15.5	1.67	9.2	46.5	51.5	58.9	1.6	6.5
1.18	50	ON	14.6	1.65	9.1	34.7	59.5	64.5	1.6	10.2
1.26	50	ON	13.9	1.68	9.2	24.2	70.4	95.8	1.9	10.5
1.34	50	ON	12.7	1.72	9.5	16.4	91.1	169.3	2.5	16.7
1.08	42	OFF	17.1	1.60	8.8	144.5	45.3	45.0	1.6	6.8
1.19	46	OFF	16.3	1.58	8.7	105.4	49.6	48.1	1.6	10.5
1.28	48	OFF	15.6	1.56	8.6	47.0	54.9	54.6	1.6	7.8
1.37	48	OFF	14.5	1.60	8.8	28.5	67.0	76.0	1.9	9.9
1,600 RPM										
1.08	50	ON	15.8	2.23	12.3	102.1	73.5	53.3	2.1	6.3
1.20	50	ON	14.7	2.27	12.5	75.6	102.9	60.1	2.5	6.7
1.26	52	ON	14.1	2.29	12.6	65.9	121.8	84.4	2.9	9.2
1.35	52	ON	12.7	2.39	13.2	38.2	151.2	195.7	4.6	21.0
1.08	44	OFF	17.0	2.23	12.3	243.2	72.7	47.0	2.1	6.7
1.19	48	OFF	16.1	2.19	12.1	192.4	82.7	48.3	2.5	6.3
1.27	50	OFF	15.4	2.19	12.1	132.7	95.3	55.9	2.5	6.7
1.37	50	OFF	14.1	2.29	12.6	70.6	128.5	94.5	3.4	10.9
2,200 RPM										
1.09	50	ON	14.2	3.74	20.6	340.2	134.6	58.6	4.6	7.5
1.22	52	ON	13.3	3.68	20.3	255.8	165.3	49.3	5.8	7.5
1.29	56	ON	12.3	3.81	21.0	219.8	222.1	81.2	8.1	9.9
1.37	56	ON	10.7	3.90	21.5	200.1	307.4	294.6	15.7	53.4
1.10	44	OFF	15.0	3.72	20.5	554.2	140.4	50.5	4.6	7.5
1.22	50	OFF	14.0	3.65	20.1	435.6	152.0	44.7	5.2	7.5
1.30	52	OFF	13.1	3.65	20.1	280.7	178.6	60.3	6.4	7.5
1.40	52	OFF	11.3	3.92	21.6	232.6	326.0	245.9	13.3	24.9

TABLE A-21 - Exhaust emissions and fuel economy (10% methanol fuel blend--MBT timing, road load, and 9.3 CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy 10^5 BTU per hr	Fuel economy lb/hr	NO_x	Before catalyst CO	Before catalyst HC	After catalyst CO	After catalyst HC
						Gram/hr				
1,200 RPM										
1.08	48	ON	14.9	1.69	9.6	34.4	53.3	62.9	1.9	7.1
1.18	50	ON	13.9	1.71	9.7	25.7	68.2	89.9	2.2	10.2
1.24	50	ON	13.2	1.74	9.9	19.8	77.5	130.5	2.5	8.1
1.33	50	ON	12.5	1.76	10.0	15.8	91.1	190.3	4.0	16.1
1.09	42	OFF	16.5	1.62	9.2	98.0	44.6	46.8	2.5	6.5
1.20	46	OFF	15.8	1.56	8.9	65.1	49.9	50.2	1.9	6.8
1.25	48	OFF	15.1	1.67	9.5	44.6	57.4	59.5	2.2	9.6
1.36	48	OFF	14.3	1.69	9.6	30.7	64.0	133.0	4.0	18.6
1,600 RPM										
1.09	50	ON	15.2	2.30	13.1	86.5	76.4	55.0	2.5	6.3
1.20	50	ON	14.1	2.34	13.3	54.6	102.5	63.4	2.9	7.1
1.26	52	ON	13.4	2.37	13.5	39.9	123.1	87.8	3.8	10.1
1.34	52	ON	12.3	2.48	14.1	35.7	155.8	188.6	5.5	19.3
1.10	44	OFF	16.3	2.23	12.7	191.1	72.2	48.7	2.5	5.9
1.20	48	OFF	15.4	2.20	12.5	120.5	84.4	47.9	2.5	5.9
1.27	50	OFF	14.8	2.25	12.8	91.1	98.3	59.6	2.9	7.1
1.38	50	OFF	13.5	2.30	13.1	40.7	125.2	96.2	4.2	10.9
2,200 RPM										
1.09	50	ON	13.5	3.67	20.9	374.1	128.2	52.2	5.8	7.0
1.21	52	ON	12.3	3.76	21.4	230.3	178.1	52.2	7.0	7.5
1.28	56	ON	11.7	3.78	21.5	191.4	213.4	73.1	8.1	10.4
1.38	56	ON	9.5	4.01	22.8	102.1	316.7	314.9	18.6	44.1
1.10	44	OFF	14.1	3.73	21.2	505.8	140.4	47.0	5.8	7.0
1.20	48	OFF	13.5	3.80	21.6	367.7	157.2	49.3	7.0	7.5
1.29	52	OFF	12.5	3.66	20.8	266.2	164.1	52.2	7.0	7.5
1.39	52	OFF	10.7	3.89	22.1	119.5	290.6	112.5	11.0	16.2

TABLE A-22. - Exhaust emissions and fuel economy (15% methanol fuel blend--MBT timing, road load, and 9.3 CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hr				
1,200 RPM										
1.08	48	ON	15.2	1.64	9.6	31.6	49.9	66.0	2.2	8.4
1.17	50	ON	14.2	1.65	9.7	24.2	64.8	88.0	2.2	12.7
1.26	50	ON	13.3	1.72	10.1	16.7	88.4	147.3	3.1	17.1
1.35	50	ON	12.5	1.74	10.2	14.9	95.8	164.0	4.0	18.0
1.08	42	OFF	16.9	1.55	9.1	100.8	43.4	50.2	2.2	7.4
1.19	46	OFF	16.1	1.55	9.1	63.9	51.8	55.8	2.2	8.1
1.27	48	OFF	15.3	1.62	9.5	36.0	61.4	66.3	2.8	10.2
1.36	48	OFF	14.3	1.65	9.7	30.1	102.0	177.9	4.3	18.3
1,600 RPM										
1.08	50	ON	15.3	2.30	13.5	76.0	82.3	56.7	2.5	8.0
1.19	50	ON	14.2	2.32	13.6	48.7	107.9	65.1	2.9	8.0
1.26	52	ON	13.5	2.39	14.0	42.0	131.8	102.5	3.8	12.2
1.36	52	ON	12.3	2.47	14.5	27.7	174.7	218.0	5.5	24.8
1.10	44	OFF	16.5	2.20	12.9	158.8	76.4	47.9	2.5	7.6
1.21	48	OFF	15.6	2.23	13.1	106.6	92.8	47.9	2.5	6.7
1.26	50	OFF	15.2	2.25	13.2	94.5	103.3	58.4	2.9	8.0
1.37	50	OFF	13.8	2.30	13.5	46.2	132.7	110.5	4.2	13.4
2,200 RPM										
1.09	50	ON	13.8	3.70	21.7	318.4	156.0	58.0	5.2	8.7
1.20	52	ON	12.5	3.75	22.0	214.9	184.4	53.4	5.8	7.5
1.27	56	ON	11.6	3.79	22.2	156.6	241.9	73.1	7.5	9.9
1.36	56	ON	10.8	4.96	23.2	133.4	313.2	418.8	16.8	40.0
1.10	44	OFF	14.5	3.68	21.6	450.7	145.0	49.9	5.2	8.7
1.20	48	OFF	13.4	3.65	21.4	342.8	161.2	43.5	5.2	7.0
1.28	52	OFF	12.6	3.68	21.6	239.5	190.2	53.4	6.4	8.1
1.37	52	OFF	10.8	3.94	23.1	151.4	312.6	182.7	12.8	21.5

TABLE A-23. - Exhaust emissions and fuel economy (100% methanol fuel blend--MBT timing, road load, and 9.3 CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^5 BTU per hour	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hour				
1,200 RPM										
1.09	46	ON	16.1	1.58	18.4	34.7	82.8	62.3	1.9	36.9
1.20	50	ON	15.4	1.55	18.1	26.0	58.6	79.4	1.9	59.2
1.28	52	ON	15.0	1.53	17.9	18.6	64.8	124.9	1.9	99.2
1.38	52	ON	14.3	1.54	18.0	10.9	86.2	159.7	2.2	140.7
1.40	52	ON	13.9	1.57	18.3	7.1	87.1	306.9	1.9	19.2
1.06	32	OFF	17.4	1.59	18.6	34.7	54.3	42.5	2.2	10.9
1.20	40	OFF	16.9	1.51	17.6	35.7	44.6	46.5	1.6	27.0
1.30	42	OFF	16.4	1.51	17.6	20.8	45.6	47.1	1.9	35.0
1.38	42	OFF	15.6	1.55	18.1	11.8	54.9	72.2	1.9	58.3
1.47	42	OFF	14.9	1.57	18.2	9.9	73.2	143.8	1.9	38.4
1,600 RPM										
1.09	42	ON	16.4	2.09	24.3	23.1	55.9	49.1	2.1	29.4
1.20	50	ON	15.7	2.05	23.9	21.0	58.4	51.7	2.5	33.6
1.26	52	ON	15.4	2.10	24.5	15.1	63.8	60.9	2.5	44.5
1.36	52	ON	14.2	2.12	24.8	7.6	87.4	73.1	3.8	60.5
1.44	52	ON	13.8	2.18	25.5	4.6	121.4	245.7	3.4	182.9
1.08	34	OFF	17.2	2.15	25.1	63.0	69.7	49.0	2.1	50.4
1.20	38	OFF	16.6	2.10	25.6	43.7	62.2	42.0	2.5	24.8
1.26	40	OFF	16.2	2.10	24.5	29.0	60.1	50.8	2.5	33.6
1.38	40	OFF	15.3	2.12	24.8	13.4	71.4	73.9	2.9	38.2
1.45	40	OFF	14.5	2.20	25.7	7.1	95.3	148.3	2.9	105.8
2,200 RPM										
1.09	36	ON	15.2	3.51	41.0	100.9	142.1	29.0	4.6	5.2
1.19	42	ON	14.6	3.41	39.8	95.7	108.5	50.5	4.1	11.0
1.28	46	ON	13.8	3.46	40.4	69.0	107.9	71.3	4.6	13.9
1.36	46	ON	12.8	3.53	41.2	34.8	121.2	129.3	5.8	26.1
1.47	46	ON	11.1	3.61	42.2	14.5	169.9	299.3	11.0	25.5
1.08	32	OFF	15.8	3.56	41.5	157.2	262.2	27.3	6.4	4.6
1.20	38	OFF	15.0	3.54	41.3	139.8	116.0	32.5	5.2	4.6
1.26	44	OFF	14.7	3.40	39.6	137.5	117.7	52.2	4.6	9.3
1.38	44	OFF	13.7	3.45	40.3	51.0	107.9	86.4	5.8	16.8
1.49	44	OFF	12.0	3.58	41.7	19.7	143.8	203.0	8.7	20.9

TABLE A-24. - Exhaust emissions and fuel economy (5% methanol fuel blend--MBT timing, road load, and 10 CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hr				
1,200 RPM										
1.08	40	ON	17.5	1.63	9.0	96.1	59.8	81.5	1.9	11.5
1.17	50	ON	15.4	1.64	9.1	74.7	71.3	123.1	2.2	15.8
1.24	52	ON	14.6	1.69	9.3	52.7	84.3	191.0	2.8	27.0
1.29	54	ON	14.3	1.76	9.7	47.1	90.2	332.0	5.0	58.3
1.08	40	OFF	17.5	1.61	8.9	187.6	42.8	53.0	1.6	9.3
1.19	46	OFF	16.9	1.56	8.6	133.6	53.6	53.0	1.9	9.3
1.28	48	OFF	16.4	1.53	8.5	78.7	57.0	60.5	1.9	9.9
1.35	52	OFF	15.8	1.63	9.0	49.9	69.4	90.8	2.2	13.3
1,600 RPM										
1.08	48	ON	16.5	2.21	12.2	140.3	76.0	61.3	2.5	7.1
1.20	50	ON	15.6	2.19	12.1	84.8	100.8	69.7	2.9	9.2
1.27	52	ON	14.9	2.20	12.2	59.9	123.1	101.6	3.8	12.6
1.34	54	ON	13.8	2.23	12.3	35.7	156.2	270.5	8.4	32.8
1.09	42	OFF	17.6	2.21	12.2	271.7	75.6	48.7	2.5	6.7
1.20	46	OFF	16.8	2.11	11.6	187.7	84.4	50.8	2.9	7.1
1.29	48	OFF	16.0	2.11	11.6	109.2	100.8	64.7	2.9	8.4
1.36	52	OFF	15.4	2.14	11.8	75.2	118.0	87.8	3.8	12.6
2,200 RPM										
1.09	40	ON	15.0	3.61	19.9	373.5	153.7	51.0	5.8	7.0
1.20	50	ON	13.9	3.60	19.8	304.8	190.2	51.6	7.5	8.1
1.28	52	ON	12.7	3.67	20.3	235.8	279.6	85.8	10.4	10.4
1.34	54	ON	11.6	3.86	21.1	192.9	384.5	281.9	19.1	37.1
1.09	42	OFF	15.7	3.62	19.9	608.4	154.9	45.8	6.4	7.5
1.20	46	OFF	14.8	3.55	19.4	465.7	164.7	45.2	6.4	7.0
1.30	48	OFF	13.9	3.66	20.0	353.8	200.7	51.0	8.7	8.7
1.36	52	OFF	12.5	3.73	20.5	311.5	328.9	138.6	13.9	13.9

TABLE A-25. - Exhaust emissions and fuel economy (10% methanol fuel blend--MBT timing, road load, and 10 CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy		NO_x	Before catalyst		After catalyst	
				10^5 BTU per hr	lb/hr		CO	HC	CO	HC
						Gram/hr				
				1,200 RPM						
1.08	48	ON	15.9	1.63	9.3	78.1	61.4	74.4	1.9	10.9
1.17	50	ON	15.2	1.65	9.4	62.6	71.3	108.8	2.2	16.1
1.26	52	ON	14.4	1.64	9.3	38.4	80.0	175.5	2.8	21.7
1.30	54	ON	13.5	1.65	9.4	36.9	82.8	245.2	3.1	24.5
1.08	40	OFF	17.5	1.58	9.0	153.8	44.3	44.6	1.9	8.7
1.20	46	OFF	16.8	1.55	8.8	115.0	52.0	49.6	1.9	9.0
1.28	48	OFF	16.2	1.54	8.8	73.5	57.4	56.1	1.9	10.2
1.37	52	OFF	15.0	1.57	8.9	40.9	66.7	76.9	2.2	12.7
				1,600 RPM						
1.09	48	ON	15.9	2.23	12.7	126.4	81.9	58.0	2.1	7.6
1.20	50	ON	15.1	2.24	12.7	79.0	110.5	76.9	2.5	8.8
1.28	52	ON	14.3	2.25	12.8	53.3	124.7	108.8	3.4	13.9
1.35	54	ON	13.4	2.29	13.0	37.8	152.5	174.7	5.5	17.6
1.10	42	OFF	17.1	2.15	12.2	242.3	72.7	40.3	2.1	5.0
1.20	46	OFF	16.4	2.12	12.1	162.1	86.5	48.3	2.5	6.3
1.30	48	OFF	15.8	2.15	12.2	107.1	95.3	55.9	2.5	5.9
1.39	54	OFF	13.4	2.13	12.1	58.4	109.6	95.9	3.4	5.9
				2,200 RPM						
1.09	48	ON	14.7	3.66	20.8	364.2	160.1	57.4	5.2	7.0
1.19	50	ON	13.7	3.66	20.8	276.7	193.1	58.0	6.4	8.1
1.26	52	ON	12.6	3.66	20.8	250.9	280.1	109.0	9.9	12.8
1.31	54	ON	11.4	3.92	22.3	176.4	361.3	489.5	24.9	77.1
1.09	42	OFF	15.3	3.67	20.9	548.7	176.3	49.9	5.2	5.8
1.20	46	OFF	14.5	3.61	20.6	412.4	175.2	49.9	5.8	7.5
1.28	48	OFF	13.6	3.63	20.7	296.4	209.4	57.4	7.5	9.9
1.35	52	OFF	12.2	4.00	22.3	233.8	367.1	233.9	19.7	40.0

TABLE A-26. - Exhaust emissions and fuel economy (15% methanol fuel blend--MBT timing, road load, and 10 CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hr				
1,200 RPM										
1.08	48	ON	15.8	1.65	9.7	72.9	60.8	80.9	1.6	14.0
1.17	50	ON	15.0	1.64	9.6	60.8	70.7	132.1	1.9	18.9
1.23	52	ON	14.7	1.66	9.7	43.4	76.0	199.0	2.2	28.2
1.31	54	ON	13.9	1.74	10.2	32.2	90.5	400.8	4.7	55.8
1.08	40	OFF	17.5	1.61	9.4	143.8	46.2	49.9	1.2	9.9
1.20	46	OFF	16.6	1.53	8.9	114.4	53.9	54.3	1.2	9.3
1.28	48	OFF	16.2	1.57	9.2	59.5	57.0	64.5	1.6	10.2
1.36	52	OFF	13.9	1.58	9.3	37.2	66.0	83.7	15.2	40.0
1,600 RPM										
1.08	48	ON	16.3	2.34	13.7	119.7	86.1	68.0	2.5	12.2
1.20	50	ON	15.5	2.35	13.8	74.3	113.0	83.2	2.9	13.9
1.26	52	ON	14.5	2.25	13.2	68.9	124.7	105.8	2.5	12.6
1.34	54	ON	13.8	2.29	13.4	44.9	158.8	221.8	3.8	27.3
1.09	42	OFF	17.4	2.23	13.1	221.3	77.3	53.3	2.5	10.9
1.20	46	OFF	16.7	2.25	12.8	167.2	93.2	58.0	2.5	10.1
1.29	48	OFF	15.9	2.16	12.7	113.8	101.6	68.0	2.1	9.7
1.37	52	OFF	15.0	2.17	12.7	84.4	119.3	100.8	2.5	13.0
2,200 RPM										
1.10	42	ON	14.5	3.59	21.1	320.5	129.3	57.4	3.5	5.8
1.20	50	ON	13.8	3.55	20.8	289.4	174.0	56.3	4.6	7.0
1.28	52	ON	12.4	3.73	21.6	230.8	261.0	82.9	7.5	11.6
1.35	54	ON	11.0	3.83	22.5	162.2	352.6	324.2	19.7	45.8
1.10	42	OFF	15.2	3.67	21.3	526.4	135.7	52.8	3.5	5.2
1.21	46	OFF	14.4	3.54	20.8	459.4	163.0	50.5	4.1	5.8
1.28	48	OFF	13.4	3.60	21.1	314.9	193.1	59.2	6.4	7.5
1.35	52	OFF	12.4	3.73	21.7	292.9	283.6	117.7	10.4	15.7

TABLE A-27. - Exhaust emissions and fuel economy (100% methanol fuel blend--MBT timing, road load, and 10 CR)

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x (Gram/hr)	Before catalyst: CO (Gram/hr)	Before catalyst: HC (Gram/hr)	After catalyst: CO (Gram/hr)	After catalyst: HC (Gram/hr)
1,200 RPM										
1.08	42	ON	16.5	1.56	18.2	22.3	41.5	29.1	1.2	18.3
1.19	46	ON	15.9	1.53	17.8	18.0	49.6	46.5	1.2	29.1
1.24	50	ON	15.6	1.53	17.8	11.5	54.3	52.1	1.2	50.8
1.36	54	ON	14.9	1.60	18.7	6.8	72.2	99.5	1.2	89.3
1.40	54	ON	14.2	1.55	18.1	4.3	86.2	161.2	1.9	142.6
1.08	32	OFF	17.8	1.53	17.9	36.3	35.7	25.7	1.2	20.2
1.18	38	OFF	17.4	1.56	18.2	22.3	41.5	29.1	1.2	18.3
1.26	42	OFF	17.0	1.47	17.2	17.4	39.1	23.6	1.2	17.4
1.38	44	OFF	16.4	1.47	17.2	8.1	46.8	42.8	1.2	38.1
1.43	44	OFF	15.6	1.52	17.7	5.3	58.9	48.4	1.6	27.0
1,600 RPM										
1.09	44	ON	16.9	2.08	24.3	39.1	51.2	26.5	1.7	14.7
1.17	48	ON	16.5	2.07	24.1	35.0	53.3	44.5	2.1	22.7
1.26	52	ON	15.8	2.05	23.9	23.5	64.7	59.2	2.1	43.3
1.30	52	ON	15.3	2.12	24.7	23.9	88.6	128.5	2.5	98.7
1.39	52	ON	14.2	2.19	25.5	19.6	119.3	231.8	2.9	156.2
1.09	34	OFF	18.0	2.04	23.8	55.4	52.1	41.2	1.7	23.9
1.20	38	OFF	17.4	2.01	23.5	39.9	47.9	30.7	1.7	18.5
1.24	42	OFF	17.0	2.07	24.1	35.7	51.2	29.4	1.7	21.8
1.32	46	OFF	16.5	2.03	23.7	16.4	59.6	50.8	2.1	30.3
1.41	46	OFF	15.5	2.05	23.9	18.9	86.9	91.6	2.5	60.1
2,200 RPM										
1.10	38	ON	15.1	3.49	40.7	83.5	116.0	24.4	5.2	8.1
1.19	46	ON	14.4	3.43	40.0	90.5	85.8	47.0	5.2	14.4
1.26	52	ON	13.7	3.44	40.1	85.8	96.3	64.4	5.2	33.1
1.35	54	ON	12.8	3.51	41.0	47.0	134.0	165.3	7.5	34.2
1.41	54	ON	12.0	3.57	41.6	41.2	172.6	465.5	10.4	126.9
1.09	32	OFF	15.7	3.56	41.5	131.7	171.7	20.9	5.8	20.3
1.20	40	OFF	15.1	3.44	40.1	118.9	88.7	40.6	5.2	10.4
1.27	44	OFF	14.5	3.39	39.5	108.5	88.7	40.0	5.2	22.0
1.36	48	OFF	13.6	3.42	39.9	78.3	108.5	94.0	7.0	29.6
1.43	48	OFF	12.6	3.51	40.9	59.7	158.3	243.0	9.9	114.3

TABLE A-28. - Exhaust emissions and fuel economy at idle--methanol fuel blends at varied compression ratios, standard timing

A/F Equivalence ratio	Manifold vacuum "Hg	Fuel economy 10^6 BTU per hour	Fuel economy lb/hr	NO_x	Without catalyst CO	Without catalyst HC	With catalyst CO	With catalyst HC
				Gram/hour				
5% MeOH STANDARD CR								
1.08	16.7	0.68	3.74	3.7	22.9	28.7	18.9	22.4
1.18	15.8	.72	3.99	3.1	26.8	33.1	7.4	11.7
1.26	14.9	.73	4.05	2.2	32.8	51.4	12.8	11.0
5% MeOH 9.3 CR								
1.07	17.4	0.69	3.78	4.4	25.5	37.5	25.2	36.7
1.17	16.5	.69	3.78	2.8	27.4	42.4	22.5	36.6
1.25	15.8	.70	3.84	2.0	30.2	55.9	10.2	22.5
5% MeOH 10 CR								
1.07	17.8	0.70	3.85	4.5	27.0	41.5	7.9	19.4
1.18	17.0	.70	3.82	3.2	30.0	47.4	18.2	31.6
1.25	16.5	.70	3.86	2.4	32.4	56.0	13.6	32.1
1.33	15.9	.72	3.95	2.1	38.6	86.8	9.3	39.1
10% MeOH STANDARD CR								
1.08	16.9	0.71	4.04	4.1	23.4	29.4	19.8	23.6
1.20	15.9	.72	4.10	2.7	26.8	36.1	12.5	9.9
1.26	15.0	.74	4.21	2.3	30.7	53.3	11.3	8.9
10% MeOH 9.3 CR								
1.07	17.3	0.68	3.86	3.7	21.7	35.8	20.7	35.1
1.17	16.4	.73	4.17	2.6	21.9	44.0	20.2	33.5
1.25	15.6	.72	4.11	1.9	30.1	54.8	7.8	22.1
10% MeOH 10 CR								
1.07	17.6	0.69	3.93	3.7	28.6	36.3	16.4	24.8
1.18	16.8	.69	3.90	2.7	31.1	40.1	22.4	32.3
1.25	16.2	.72	4.07	2.1	36.0	54.6	16.3	34.1
1.33	15.3	.74	4.19	2.1	42.7	92.6	14.8	23.1

TABLE A-28. - Exhaust emissions and fuel economy at idle--methanol fuel blends at varied compression ratios, standard timing--continued

A/F Equivalence ratio	Manifold vacuum "Hg	Fuel economy: 10^5 BTU per hour	Fuel economy: lb/hr	NO_x	Without catalyst: CO	Without catalyst: HC	With catalyst: CO	With catalyst: HC
				Gram/hour				
15% MeOH STANDARD CR								
1.10	16.4	0.70	4.07	3.5	23.5	29.9	13.2	27.5
1.23	15.4	.71	4.17	2.7	26.7	37.8	6.4	15.1
1.31	14.7	.72	4.23	1.7	32.5	47.1	8.3	12.3
15% MeOH 9.3 CR								
1.08	17.3	0.70	4.13	3.5	26.4	40.4	26.4	38.1
1.18	16.2	.71	4.19	2.1	28.4	45.5	26.2	43.8
1.26	15.3	.72	4.25	1.7	32.0	57.4	10.7	28.8
15% MeOH 10 CR								
1.07	17.7	0.68	3.98	3.8	27.4	36.7	11.1	18.0
1.18	17.1	.69	4.03	2.9	30.8	44.0	20.0	36.0
1.25	16.5	.70	4.12	2.2	34.2	56.2	13.6	38.8
1.33	15.8	.72	4.24	2.0	39.1	94.1	18.0	28.0
100% MeOH STANDARD CR								
1.09	17.0	0.85	9.9	2.2	26.7	31.1	5.0	5.5
1.20	16.2	.83	9.6	2.0	27.7	34.0	8.9	8.4
1.25	15.9	.86	10.0	1.4	33.0	41.6	5.0	10.5
1.36	15.2	.93	10.8	.9	48.7	78.3	8.8	29.8
100% MeOH 9.3 CR								
1.06	18.0	0.64	7.5	1.1	33.2	32.9	8.2	30.0
1.18	17.4	.64	7.5	.9	27.5	37.5	7.4	27.4
1.25	16.7	.68	7.9	.9	59.1	56.0	7.9	44.5
1.33	16.1	.65	7.6	.8	43.3	57.6	8.4	54.0
100% MeOH 10 CR								
1.09	18.1	0.63	7.4	1.6	26.6	22.0	6.4	19.8
1.20	17.6	.64	7.5	1.6	22.5	29.4	5.9	17.8
1.29	16.6	.63	7.4	1.0	27.6	31.0	6.3	25.6
1.38	16.1	.63	7.4	.6	38.7	68.4	7.3	45.2
1.46	15.2	.71	8.3	.6	55.3	94.3	7.4	67.3

TABLE A-29. - Exhaust emissions and fuel economy at varied speeds--5% methanol, standard timing, road load, and standard CR

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy		NO_x	Before catalyst		After catalyst	
				10^5 BTU per hr	lb/hr		CO	HC	CO	HC
						Gram/hr				
600 RPM										
1.08	24	OFF	16.7	0.68	3.74	3.7	22.9	28.7	18.9	22.4
1.18	24	OFF	15.8	.72	3.99	3.1	26.8	33.1	7.4	11.7
1.26	24	OFF	14.9	.73	4.05	2.2	32.8	51.4	2.8	11.0
1,200 RPM										
1.09	24	ON	12.5	0.09	11.5	22.0	91.5	36.3	6.5	8.1
1.20	24	ON	10.8	2.04	11.2	12.1	125.9	50.8	6.5	5.9
1.25	24	ON	9.6	2.25	12.4	7.8	120.6	82.2	4.3	5.6
1.09	24	OFF	15.8	1.74	9.6	49.9	54.9	27.3	13.0	7.4
1.20	24	OFF	14.5	1.82	10.0	24.5	62.9	25.7	3.7	7.8
1.28	24	OFF	13.1	1.89	10.4	16.1	87.4	33.5	6.5	4.7
1.37	24	OFF	11.4	2.06	11.4	11.2	140.1	103.2	9.3	7.8
1,600 RPM										
1.08	30	ON	14.2	2.74	15.1	39.5	124.7	25.2	5.0	2.5
1.20	30	ON	12.2	2.78	15.3	25.2	146.6	27.7	2.9	3.8
1.27	30	ON	10.8	2.93	16.2	24.4	262.5	226.0	4.2	8.4
1.09	30	OFF	16.3	2.45	13.5	102.9	90.7	25.2	2.9	2.1
1.20	30	OFF	14.9	2.47	13.6	53.8	105.4	20.2	2.5	2.1
1.27	30	OFF	13.8	2.59	14.2	50.8	163.0	79.4	4.2	4.2
1.36	30	OFF	11.7	2.72	15.0	23.5	210.4	134.8	6.3	8.4
2,200 RPM										
1.11	38	ON	12.8	3.78	20.8	176.3	149.1	23.2	4.1	2.9
1.19	38	ON	11.8	3.98	21.8	151.4	227.4	34.8	6.4	2.9
1.27	38	ON	10.2	4.10	22.6	130.5	361.9	190.2	11.6	13.9
1.10	38	OFF	14.1	3.70	20.4	360.2	141.5	26.1	4.1	3.5
1.19	38	OFF	13.1	3.69	20.3	254.0	154.3	20.9	4.1	2.9
1.26	38	OFF	11.9	3.91	21.5	194.3	270.9	45.2	7.0	4.6
1.33	38	OFF	9.3	4.40	24.2	163.6	561.4	533.0	18.6	21.5

TABLE A-30. - Exhaust emissions and fuel economy at varied speeds--10% methanol, standard timing, road load, and standard CR

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy		NO_x	Before catalyst		After catalyst	
				10^5 BTU per hr	lb/hr		CO	HC	CO	HC
						Gram/hr				
600 RPM Idle										
1.08	24	OFF	16.9	4.04	0.71	4.1	23.4	29.4	19.8	23.6
1.20	24	OFF	15.9	4.10	.72	2.7	26.8	36.1	2.5	9.9
1.26	24	OFF	15.0	4.21	.74	2.3	30.7	53.3	1.3	8.9
1,200 RPM										
1.09	24	ON	12.5	2.03	11.5	21.4	93.6	42.2	2.5	4.3
1.20	24	ON	11.0	2.12	12.0	12.4	123.1	46.5	2.5	4.0
1.27	24	ON	9.8	2.18	12.4	11.5	169.6	105.1	3.1	7.8
1.10	24	OFF	16.1	1.77	10.0	44.6	57.0	23.9	2.8	3.7
1.20	24	OFF	14.3	1.77	10.0	24.2	69.1	28.2	2.5	3.1
1.30	24	OFF	12.5	1.95	11.0	16.7	94.6	38.4	2.5	6.5
1.36	24	OFF	11.6	2.07	11.7	10.5	129.6	72.9	6.2	4.7
1,600 RPM										
1.09	30	ON	14.1	2.65	15.0	37.0	71.4	19.3	2.1	2.1
1.21	30	ON	12.5	2.70	15.3	26.9	161.3	38.6	2.5	3.8
1.26	30	ON	11.3	2.88	16.4	22.3	244.4	117.2	5.0	6.7
1.09	30	OFF	16.5	2.39	13.6	101.2	84.4	22.3	2.5	2.1
1.20	30	OFF	15.1	2.40	13.6	56.3	103.3	23.5	2.1	2.5
1.31	30	OFF	13.3	2.62	14.9	24.4	148.7	36.1	2.9	3.8
1.34	30	OFF	12.1	2.71	15.4	30.2	182.7	120.5	4.2	8.4
2,200 RPM										
1.09	38	ON	13.4	3.76	21.3	154.3	164.1	41.8	5.8	5.2
1.19	38	ON	11.8	3.90	22.1	111.4	203.0	38.9	6.4	3.5
1.30	38	ON	10.0	3.89	22.1	60.3	252.9	87.6	6.4	7.5
1.09	38	OFF	14.8	3.69	20.9	348.0	237.8	31.3	5.2	3.5
1.19	38	OFF	13.4	3.68	20.8	330.0	172.8	31.9	6.4	3.5
1.25	38	OFF	12.1	3.70	21.0	218.7	203.0	40.0	7.5	3.5
1.36	38	OFF	9.2	4.23	24.0	145.0	296.4	74.2	7.5	7.0

TABLE A-31. - Exhaust emissions and fuel economy at varied speeds--15% methanol, standard timing, road load, and standard CR

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hr				
600 RPM IDLE										
1.10	24	OFF	16.4	0.70	4.07	3.5	23.5	29.9	13.2	27.5
1.23	24	OFF	15.4	.71	4.17	2.7	26.7	37.8	6.4	15.1
1.31	24	OFF	14.7	.72	4.23	1.7	32.5	47.1	5.3	12.3
1,200 RPM										
1.09	24	ON	12.1	2.04	11.9	17.1	88.0	32.9	5.0	7.8
1.19	24	ON	10.8	2.10	12.3	10.5	117.2	52.4	6.5	9.3
1.23	24	ON	10.4	2.19	12.8	5.6	169.6	117.2	2.2	9.9
1.09	24	OFF	15.5	1.81	10.5	44.3	57.0	27.2	5.3	6.5
1.20	24	OFF	14.3	1.83	10.7	23.6	67.3	31.3	5.3	7.4
1.32	24	OFF	12.6	1.91	11.1	12.4	91.8	42.2	5.6	8.4
1.36	24	OFF	11.5	2.06	12.0	10.2	118.1	109.1	9.3	10.9
1,600 RPM										
1.10	30	ON	13.5	2.51	14.7	36.5	99.5	30.7	5.0	1.7
1.20	30	ON	12.4	2.69	15.7	24.8	138.2	31.9	13.0	8.8
1.28	30	ON	10.4	2.88	16.8	19.3	240.2	140.3	10.9	17.2
1.09	30	OFF	15.4	2.54	14.8	91.1	78.5	29.0	6.7	2.9
1.21	30	OFF	14.4	2.51	14.7	44.1	103.7	29.8	4.6	2.1
1.29	30	OFF	13.4	2.57	15.0	29.8	140.3	37.4	10.9	8.0
1.36	30	OFF	12.1	2.74	16.0	21.8	198.7	144.9	12.6	10.5
2,200 RPM										
1.09	38	ON	13.0	3.87	22.6	156.6	160.1	28.4	4.6	2.9
1.20	38	ON	11.3	3.97	23.1	96.9	199.5	26.1	2.3	2.3
1.29	38	ON	9.3	4.23	24.7	55.7	334.1	80.0	6.4	6.4
1.10	38	OFF	14.0	3.87	22.6	205.3	140.9	16.2	4.6	2.3
1.18	38	OFF	13.0	3.87	22.6	191.4	174.6	24.9	5.2	2.9
1.30	38	OFF	11.1	4.00	23.3	95.7	237.2	35.4	7.0	3.5
1.32	38	OFF	10.0	4.10	23.9	95.5	503.4	524.9	25.5	31.9

TABLE A-32. - Exhaust emissions and fuel economy at varied speeds--100% methanol, standard timing, road load, and standard CR

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hr				
600 RPM IDLE										
1.09	24	OFF	17.0	0.85	9.9	2.2	26.7	31.1	5.0	5.5
1.20	24	OFF	16.2	.83	9.6	2.0	27.7	34.0	2.9	8.4
1.25	24	OFF	15.9	.86	10.0	1.4	33.0	41.6	5.0	10.5
1.36	24	OFF	15.2	.93	10.8	.9	48.7	78.3	3.8	29.8
1,200 RPM										
1.10	24	ON	13.8	1.95	22.8	4.7	52.4	38.4	6.2	4.7
1.20	24	ON	12.8	1.96	22.8	3.4	69.1	58.9	6.2	4.0
1.27	24	ON	12.0	2.03	23.7	3.1	94.6	106.0	3.7	5.3
1.34	24	ON	10.8	2.10	24.5	3.1	122.5	269.4	6.2	8.1
1.10	24	OFF	16.5	1.76	20.5	24.8	58.0	33.8	6.2	4.7
1.16	24	OFF	15.6	1.86	21.7	16.1	46.2	42.8	3.7	4.7
1.28	24	OFF	15.1	1.89	22.1	10.2	57.7	58.9	1.9	4.7
1.39	24	OFF	13.4	1.91	22.3	7.4	79.4	86.5	6.2	7.4
1,600 RPM										
1.09	30	ON	15.6	2.49	29.1	16.0	74.3	42.2	2.9	8.0
1.20	30	ON	14.4	2.54	29.6	11.3	76.9	63.8	4.6	8.4
1.24	30	ON	14.3	2.69	31.4	8.4	92.0	76.9	5.9	7.1
1.38	30	ON	12.7	2.61	30.5	5.5	131.9	158.8	6.7	4.6
1.09	30	OFF	17.2	2.41	28.2	59.6	94.1	31.1	3.8	8.0
1.20	30	OFF	16.8	2.43	28.4	36.1	79.8	49.1	4.6	8.0
1.27	30	OFF	15.7	2.34	27.3	19.7	72.2	65.9	4.6	20.6
1.39	30	OFF	14.3	2.50	29.2	10.9	92.4	149.9	7.6	5.0
2,200 RPM										
1.09	38	ON	14.2	3.87	45.1	78.3	153.7	49.3	7.5	44.1
1.19	38	ON	14.0	3.79	44.3	53.4	124.7	62.1	9.9	32.5
1.26	38	ON	12.3	3.93	45.8	30.2	121.8	84.7	11.0	36.0
1.35	38	ON	10.9	4.03	47.0	13.3	158.9	134.6	11.6	33.6
1.09	38	OFF	14.9	3.88	45.2	110.7	34.8	29.0	26.7	7.5
1.20	38	OFF	14.0	3.64	42.5	107.3	174.0	60.3	13.9	20.9
1.28	38	OFF	13.8	3.60	42.0	58.0	140.4	93.4	11.0	17.4
1.38	38	OFF	12.8	3.75	43.8	25.5	132.8	120.1	11.0	18.0

TABLE A-33. - Exhaust emissions and fuel economy at varied speeds--5% methanol, timing retarded from MBT, road load, and standard CR

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hr				
600 RPM										
1.08	6	OFF	14.8	0.85	4.71	4.2	28.0	18.4	5.6	5.8
1.20	6	OFF	13.0	.88	4.87	2.7	32.8	20.5	1.1	3.1
1.26	6	OFF	11.8	.99	5.48	2.0	42.7	24.8	1.2	3.7
1,200 RPM										
1.08	36	ON	13.6	1.96	10.8	35.7	83.4	56.7	7.1	8.4
1.19	38	ON	12.4	1.79	9.9	19.2	108.2	79.7	8.4	7.1
1.25	42	ON	11.8	1.81	10.0	12.7	121.2	146.0	9.0	11.8
1.09	32	OFF	16.4	1.67	9.2	71.9	48.7	31.9	9.6	9.0
1.20	34	OFF	15.4	1.68	9.2	38.1	57.0	32.6	5.3	8.4
1.25	38	OFF	14.2	1.71	9.4	22.9	71.9	45.6	7.4	5.3
1.38	38	OFF	12.5	1.85	10.2	13.6	107.9	93.3	10.9	9.3
1,600 RPM										
1.09	38	ON	14.5	2.49	13.7	53.8	110.8	32.8	4.2	2.9
1.19	42	ON	13.5	2.53	13.9	34.0	151.2	39.9	2.5	3.4
1.27	44	ON	12.3	2.59	14.2	28.6	202.4	185.6	1.7	8.8
1.09	36	OFF	16.6	2.33	12.8	128.9	84.8	30.7	3.8	2.9
1.20	38	OFF	15.5	2.38	13.1	76.0	103.7	26.5	2.9	2.5
1.29	42	OFF	14.3	2.45	13.5	60.9	156.2	82.7	5.5	4.2
1.37	42	OFF	12.7	2.57	14.2	31.9	186.1	112.6	6.3	10.1
2,200 RPM										
1.10	44	ON	13.1	3.62	19.9	227.9	138.0	31.3	3.5	3.5
1.19	44	ON	12.0	3.85	21.2	169.4	221.6	37.7	5.8	2.9
1.29	46	ON	10.4	3.96	21.8	156.0	331.8	140.4	11.0	16.2
1.10	38	OFF	14.1	3.70	20.4	360.2	141.5	26.1	4.1	3.5
1.20	44	OFF	13.1	3.63	20.0	273.8	158.9	25.5	4.1	2.9
1.28	44	OFF	12.0	3.87	21.3	164.2	248.2	45.2	6.4	4.6
1.35	44	OFF	10.2	4.13	22.7	104.7	439.1	307.4	12.6	22.0

TABLE A-34. - Exhaust emissions and fuel economy at varied speeds--10% methanol, timing retarded from MBT, road load, and standard CR

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hr				
600 RPM										
1.09	6	OFF	14.8	0.86	4.90	4.3	27.1	-	-	-
1.21	6	OFF	13.1	.89	5.05	3.0	32.9	-	-	-
1.29	6	OFF	11.5	.97	5.53	2.4	-	-	-	-
1,200 RPM										
1.08	38	ON	13.8	1.83	10.4	31.6	84.1	66.3	2.2	2.8
1.18	40	ON	12.7	1.82	10.3	24.5	112.2	111.9	2.2	1.6
1.27	44	ON	11.8	1.84	10.4	17.1	128.3	176.1	2.5	5.6
1.09	32	OFF	16.6	1.69	9.6	62.9	51.5	30.4	2.2	1.6
1.20	36	OFF	15.5	1.69	9.6	44.0	60.8	37.2	1.9	1.6
1.32	40	OFF	14.2	1.72	9.8	23.9	70.7	49.3	1.6	1.6
1.39	40	OFF	13.1	1.80	10.2	14.0	93.9	82.2	3.1	4.0
1,600 RPM										
1.09	38	ON	14.6	2.51	14.2	50.0	72.7	29.0	2.1	2.9
1.20	42	ON	13.4	2.48	14.1	33.6	142.9	44.9	2.1	3.8
1.26	44	ON	12.7	2.52	14.3	25.2	186.1	102.1	4.2	8.8
1.09	34	OFF	16.8	2.38	13.5	123.1	58.0	27.7	1.7	2.9
1.21	38	OFF	15.6	2.38	13.5	84.4	103.3	28.6	2.1	2.5
1.31	42	OFF	14.4	2.40	13.6	53.8	133.6	42.2	2.5	4.2
1.35	42	OFF	13.1	2.53	14.4	42.0	180.6	145.7	6.3	12.6
2,200 RPM										
1.09	44	ON	14.4	3.67	20.8	233.5	229.1	44.1	5.2	5.2
1.20	44	ON	12.2	3.74	21.2	144.4	197.2	30.7	6.4	2.9
1.28	46	ON	10.8	3.77	21.4	125.3	294.6	91.6	7.5	10.4
1.09	38	OFF	14.8	3.69	20.9	331.8	182.7	29.0	5.2	2.9
1.19	44	OFF	13.7	3.66	20.8	280.1	174.0	26.1	5.8	2.9
1.26	44	OFF	12.6	3.65	20.7	134.6	201.3	31.3	7.0	2.9
1.36	44	OFF	10.7	3.94	22.4	92.8	314.9	111.9	8.1	7.5

TABLE A-35. - Exhaust emissions and fuel economy at varied speeds--15% methanol, timing retarded from MBT, road load, and standard CR

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy: 10^5 BTU per hr	Fuel economy: lb/hr	NO_x	Before catalyst: CO	Before catalyst: HC	After catalyst: CO	After catalyst: HC
						Gram/hr				
600 RPM Idle										
1.09	6	OFF	14.6	0.84	4.90	3.7	26.9	19.0	12.2	11.6
1.22	6	OFF	13.0	.90	5.30	2.4	33.1	23.4	5.1	9.0
1.32	6	OFF	11.6	.92	5.40	1.8	43.5	29.5	5.6	10.0
1,200 RPM										
1.08	38	ON	13.5	1.85	10.8	26.4	80.0	62.9	5.9	10.9
1.21	40	ON	12.4	1.83	10.7	18.0	113.2	105.4	4.0	12.7
1.29	44	ON	11.6	1.82	10.6	12.7	128.0	155.6	2.8	11.5
1.09	32	OFF	16.1	1.71	10.0	61.7	51.2	32.9	5.6	7.4
1.20	38	OFF	15.4	1.67	9.8	44.0	58.6	40.0	5.3	9.0
1.32	40	OFF	14.1	1.71	10.0	23.3	71.9	49.0	4.0	10.5
1.38	40	OFF	13.3	1.80	10.5	15.8	86.8	73.2	6.2	12.4
1,600 RPM										
1.09	38	ON	14.0	2.47	14.4	48.7	102.9	42.8	11.8	3.4
1.20	42	ON	13.4	2.47	14.4	33.6	147.8	53.8	11.8	8.8
1.27	44	ON	12.3	2.51	14.7	21.4	176.0	106.7	9.7	13.4
1.09	34	OFF	15.8	2.45	14.3	107.1	79.4	33.2	6.3	3.4
1.21	38	OFF	15.4	2.46	14.3	83.2	117.6	41.6	13.9	10.1
1.29	40	OFF	14.3	2.39	14.0	44.9	130.2	46.6	10.5	7.6
1.35	42	OFF	13.5	2.51	14.7	41.6	177.7	165.1	14.7	12.6
2,200 RPM										
1.09	44	ON	13.3	3.81	22.2	200.1	161.8	38.9	4.6	3.5
1.19	44	ON	11.9	3.82	22.3	119.5	189.7	31.3	5.2	2.9
1.26	44	ON	10.5	3.94	23.0	78.9	302.8	98.0	7.0	7.0
1.10	38	OFF	14.0	3.87	22.6	250.0	140.9	16.2	4.6	2.3
1.19	44	OFF	13.2	3.81	22.2	205.3	179.8	29.0	5.2	2.9
1.28	44	OFF	11.8	3.88	22.6	121.2	219.2	36.5	6.4	3.5
1.32	44	OFF	10.6	4.09	23.9	132.0	435.0	421.1	13.9	20.9

TABLE A-36. - Exhaust emissions and fuel economy at varied speeds--100% methanol, timing retarded from MBT, road load, and standard CR

A/F Equivalence ratio	Timing, °BTC	EGR	Manifold vacuum, "Hg	Fuel economy 10^5 BTU per hour	Fuel economy lb/hr	NO_x	Before catalyst CO	Before catalyst HC	After catalyst CO	After catalyst HC
						Gram/hour				
				600 RPM						
1.09	6	OFF	15.6	0.98	11.5	2.11	22.5	22.7	3.2	7.6
1.20	6	OFF	14.3	1.03	12.0	1.67	23.3	27.5	3.2	7.6
1.27	6	OFF	13.3	1.04	12.1	1.02	27.9	32.8	5.0	8.4
1.38	6	OFF	11.6	1.25	14.6	.85	48.9	57.1	3.8	21.8
				1,200 RPM						
1.09	34	ON	14.5	1.83	21.3	5.0	49.0	49.3	5.0	5.3
1.19	40	ON	13.8	1.82	21.2	4.7	59.5	68.8	6.2	2.4
1.27	40	ON	13.5	1.94	22.6	4.3	72.9	84.3	3.1	4.7
1.35	40	ON	12.4	1.86	21.7	3.1	97.7	181.4	6.8	5.3
1.10	24	OFF	16.5	1.76	20.5	24.8	58.0	33.8	6.2	4.7
1.20	30	OFF	16.0	1.78	20.8	23.9	63.2	57.4	3.1	4.7
1.28	30	OFF	15.6	1.83	21.3	14.3	60.8	64.2	3.7	5.3
1.36	32	OFF	14.3	1.88	21.9	8.7	64.8	73.8	5.0	5.6
				1,600 RPM						
1.09	38	ON	16.1	2.36	27.5	19.3	72.7	44.5	2.9	5.9
1.20	38	ON	14.8	2.43	28.4	14.3	78.5	84.4	4.6	5.9
1.26	40	ON	13.2	2.51	29.3	9.7	89.5	88.6	4.6	13.0
1.39	40	ON	13.4	2.49	29.1	8.0	116.8	73.5	6.7	3.8
1.10	24	OFF	16.8	2.45	28.6	38.6	93.7	31.1	4.6	8.0
1.20	30	OFF	16.8	2.43	28.4	34.0	79.8	49.1	4.6	8.0
1.28	36	OFF	16.2	2.37	27.6	31.5	79.0	57.5	5.0	4.6
1.39	36	OFF	14.9	2.38	27.8	13.9	88.6	117.2	6.7	6.3
				2,200 RPM						
1.09	30	ON	13.8	3.95	46.1	45.8	138.6	31.3	3.5	38.9
1.19	38	ON	14.0	3.80	44.3	53.4	124.7	62.1	9.9	32.5
1.26	46	ON	12.7	3.87	45.1	41.2	123.5	94.0	11.0	34.2
1.37	46	ON	12.0	3.82	44.6	25.5	143.8	145.0	11.6	37.7
1.09	20	OFF	14.9	4.04	47.2	75.4	25.5	32.5	24.9	6.4
1.20	34	OFF	14.0	3.64	42.5	78.9	158.9	63.2	11.6	13.3
1.27	30	OFF	13.3	3.76	43.9	37.1	131.7	85.8	11.6	18.0
1.37	44	OFF	13.3	3.67	42.8	43.5	138.0	121.8	11.0	18.0

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