

Supportive Information Report for the
Fuel Economy Measurement Test
(Engineering Type) for
Trucks and Buses—
SAE J1420 JUL83

SAE Information Report
Approved July 1983

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SUPPORTIVE INFORMATION REPORT FOR THE FUEL ECONOMY MEASUREMENT TEST (ENGINEERING TYPE) FOR TRUCKS AND BUSES—SAE J1420 JUL83

SAE Information Report

Report of the Truck and Bus Fuel Economy Committee, approved July 1983.

1. This information report is a companion document to SAE Recommended Practice, J1376, Fuel Economy Measurement Test (Engineering Type) for Trucks and Buses. It provides background information and explanations to better understand the measurement procedure and its use. It also provides references and data which were developed by the SAE/DOT Program in support of the particular limitations or parameters selected for the various items in the test procedure. The format used in this document is similar to the recommended practice so that corresponding topics can be found under the same headings.

1.1 Overview—The objective of this test procedure is to enable one to conduct a relatively simple test employing driving patterns for the purpose of evaluating relative fuel economy expressed in mpg between vehicles or the effects of various devices on fuel economy when these devices are installed on a vehicle.

The test procedure requires a reference or a control vehicle to be run simultaneously with the test vehicle on the same course and at the same time. The mpg ratio of the control vehicle to the test vehicle is applied to check the repeatability and validity of the test results. The corrections applied to the observed mpg are: (1) the test fuel heating value is corrected to standard fuel heating value, and (2) the corrected fuel density is to standard 60°F fuel temperature. At the time of this writing, not enough test data has been generated to develop a correction factor for ambient temperature and barometric pressure. To minimize the effect of the ambient temperature, the test procedure recommends a rather narrow temperature band.

2. Scope—This information report provides background information related to the development of the SAE Recommended Practice that produces relative fuel economy data.

3. Definitions

3.1 Test Cycles—The criterion in the development of the test cycles was to have relatively simple test cycles which in many cases could be run on a public highway if a suitable test track were not available. A complicated test cycle could cause the drivers to neglect safety and adequate attention to the driving pattern and also increase the manpower required to conduct the test. Universal test cycles to reflect the real world are impossible to develop. The driving patterns in the real world are changing—less idle time, slower speeds, and closer selection of gears. By developing simple test cycles, a more complicated driving pattern to fit someone's specific needs can be approximated by combining portions of the recommended test cycles, such as 50% of the long haul and 50% of the short haul into a specialized test cycle.

Relatively short test cycles are desirable. More test cycles can be run in a given time frame and more data points collected. Also, test repeatability problems and other errors can be noticed early and corrected. The test procedure provides the means for evaluating only the relative fuel economy of a vehicle or vehicles. It provides a measure of percent change in fuel economy due to a modification of a test vehicle or a change in a vehicle's mode of operation from a baseline condition.

An absolute mpg value at standard ambient conditions cannot be easily obtained. It is not known what the correction factor for ambient conditions for the various types of vehicles should be. If a reference vehicle is available with a known mpg value at the standard conditions, an approximate absolute value can be obtained but very few organizations have a reference vehicle.

The procedure provides means for obtaining data for possible fuel savings calculations or fuel economy calculations at some ambient conditions other than standard. This is illustrated in Fig. 1 where the relative improvement in fuel economy between radial versus bias ply tires is shown based on actual test data.

3.1.1 LONG HAUL CYCLE—Refer to SAE Paper 831784, Development of Fuel Economy Test Procedures by Richard S. Johnson, presented at the 1983 Truck and Bus Meeting and Exposition, November 7-10, 1983.

3.1.2 SHORT HAUL CYCLE—Refer to SAE Paper 831784, Development of Fuel Economy Test Procedures by Richard S. Johnson, presented at the 1983 Truck and Bus Meeting and Exposition, November 7-10, 1983.

3.1.3 LOCAL CYCLE—Refer to SAE Paper 831784, Development of Fuel Economy Test Procedures by Richard S. Johnson, presented at the 1983 Truck and Bus Meeting and Exposition, November 7-10, 1983.

3.1.4 TRANSIT CYCLE—Refer to "Baseline Advanced Design Transit Coach Specification," Part II paragraph 1.2, published by DOT.

3.2 Test Vehicles

3.2.1 MODEL IDENTIFICATION—No background information is required.

3.2.2 COMPONENT IDENTIFICATION—No background information is required.

3.2.3 CONTROL VEHICLE—The ambient conditions during a test can change and do change. To neutralize these effects, the control vehicle is employed. The assumption is made that the test vehicle and control vehicle are affected by the changes in the ambient conditions in the same manner, thus changing the power requirements of both vehicles proportionally by the same amount.

The control vehicle is run together with the test vehicle at some reasonable distance so as not to change the aerodynamic conditions of the vehicle running behind.

Test data indicate that this method of testing provides good test-to-test repeatability and early detection of errors in driving the cycle. It provides a reliable tool for evaluating the test results. The same control vehicle must be used during the duration of any specific series of tests. If a prolonged series of tests is expected, the control vehicle must be maintained so as to give identical results under the same ambient conditions each time the same test cycle is run. Test data indicate that a relatively large aerodynamic difference can exist between the test and the control vehicles and still provide reliable test data.

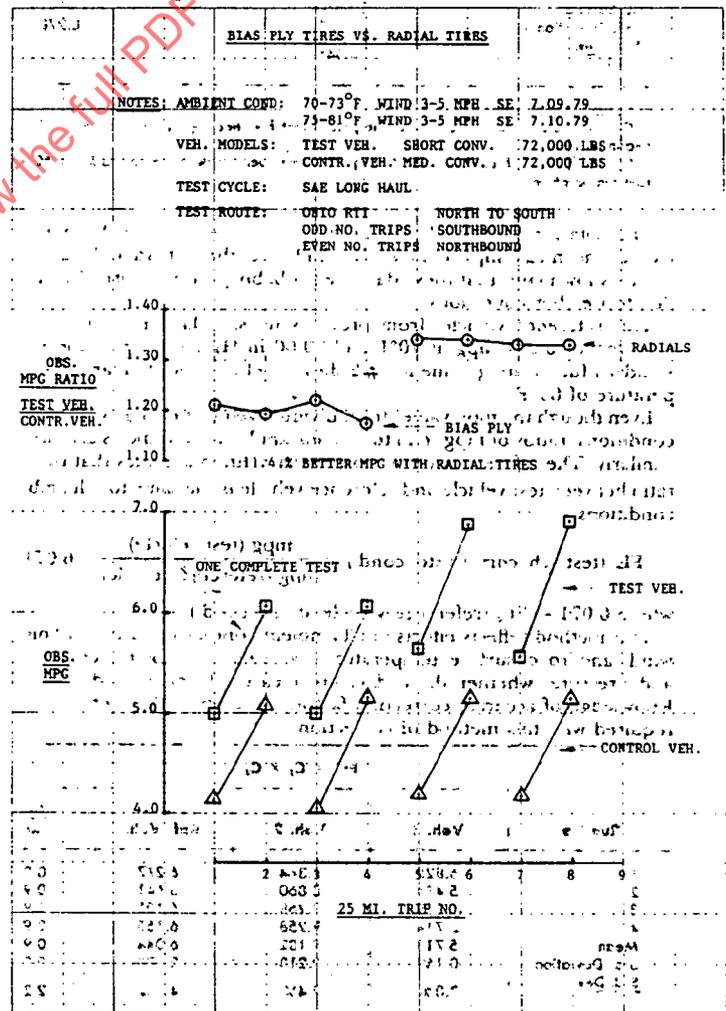


FIG. 1

In the calculation of the test results, the mpg ratio of the two vehicles is used. Regardless of the ambient conditions, the ratio remains approximately the same (as shown in Fig. 1) for all the same test runs. Any substantial change in the ratio usually indicates a bad run.

A reference vehicle can be employed in place of a control vehicle in conducting the tests. A reference vehicle is a control vehicle for which the fuel economy is known at reference conditions of 70°F ambient and 29.00 in Hg barometric pressure with fuel of standard heating value. If a reference vehicle were available, a rough estimate of absolute mpg values of a vehicle on a specific test cycle at reference conditions could be attained. For a one time test only, relative values can be obtained. Because very few organizations have such a vehicle, the test procedure deals only with the use of the control vehicle. A sample calculation employing a reference vehicle is shown below.

Sample Calculation with Reference Vehicle—A reference vehicle was tested simultaneously with the test vehicle and the control vehicle shown in paragraph 11.5 of the test procedure. (Ambient conditions are the same as in paragraph 11.5).

**REFERENCE VEHICLE DIESEL POWERED
(30.12 Miles)**

Run No.	Obs. Gal.	Fuel* Temp °F	FE _o Obs. mpg	C ₁ C.F. to Std. H.V.	C ₂ C.F. to 60°F Fuel	FE _c Corr. mpg
1	4.78	86.0	6.301	0.9860	1.0104	6.277
2	5.32	86.0	5.662	0.9860	1.0104	5.641
3	4.90	78.5	6.147	0.9860	1.0073	6.105
4	4.87	83.0	6.185	0.9860	1.0092	6.115
Mean			6.074			6.0445
% Spread			10.5%			10.5%
Std. Deviation			0.282			0.278
Std. Dev. Mean			4.64%			4.61%

* Same fuel as vehicle 2.

C₁—Multiplying factor to correct mpg from test fuel heating value to standard fuel heating value.

C₂—Multiplying factor to correct mpg from test fuel temperature to standard 60°F fuel temperature.

The data for run No. 2 may appear to be questionable. Without run No. 2, the mean mpg column is 6.211 and the spread only 2.8%. It will be shown later that these data are probably part of a normal variation due to weather conditions.

This reference vehicle, from previous tests, is known to have a fuel economy of 6.071 mpg at 70°F and 29.00 in Hg after correction to the standard fuel heating value for #2 diesel fuel and the standard fuel temperature of 60°F.

Even though the mpg values for individual vehicles change with weather conditions, ratios of mpg tend to be constant because vehicles are affected similarly. The reference vehicle correction method assumes that the mpg ratio between test vehicle and reference vehicle is the same for all ambient conditions.

$$FE_c (\text{test veh. corr. to std. cond.}) = \frac{\text{mpg (test vehicle)}}{\text{mpg (reference vehicle)}} \times 6.071$$

where 6.071 = FE_c (reference vehicle at std. cond.)

This method reflects effects of all ambient conditions such as humidity, wind, and road surface temperatures, as well as ambient temperature and pressure, whether these data are measured and recorded or not. Knowledge of accurate correction factors for each of these effects is not required with this method of correction.

Ambient conditions are the same for two or more vehicles tested together. Fuel type and fuel temperatures are not necessarily the same. The ratio of observed fuel economies is not adequate for this method unless by the volumetric method.

$$\frac{FE_o (\text{test vehicle})}{FE_o (\text{reference vehicle})} = \frac{FE_o \times C_1 \times C_2 (\text{test vehicle})}{FE_o \times C_1 \times C_2 (\text{reference vehicle})}$$

For the example, the factors C₁ and C₂ are almost the same for vehicle 2 and the reference vehicle (same fuel and same fuel temperature within 2.5°F) so FE_o/FE_o could be used. Vehicle 1 burned gasoline and had a different fuel temperature. The factor FE_o × C₁ × C₂ and the corrected FE_c have been calculated for all three vehicles.

The mpg values corrected by the reference vehicle method should be close to those which would be observed if these vehicles ran the same test cycle with standard fuel and at standard atmospheric conditions.

Vehicle 1	5.74 mpg
Vehicle 2	9.23 mpg
Ref. Veh.	6.07 mpg

Test vehicle 2 gives 60.8% better mpg than test vehicle 1 (mean ratio is 1.608).

Test vehicle 1 gives 5.5% lower mpg than the reference vehicle (ratio is 0.945).

Test vehicle 2 gives 52.0% better mpg than the reference vehicle (ratio is 1.520).

Run No. 2 appeared to give a questionable low mpg value for the reference vehicle in the previous tabulation. Vehicles 1 and 2 also showed low mpg values for run No. 2, but the mpg ratios of these vehicles relative to the reference vehicle are 0.970 and 1.571 with only 2.2% and 2.3% coefficient of variation. Some unrecorded test condition has caused the mpg values for all three vehicles to be low. The mpg ratio is relatively unchanged.

The same effect, that the mpg ratio is much more consistent than mpg values, is also clearly shown in Figs. 1 and 2. The mpg values northbound and southbound on Fig. 1 show 23% better economy northbound than southbound, but the ratios show little effect. The ratios on Fig. 2 also show much less variation than do the mpg values for the four test runs, the three road runs, and all seven runs together. The mpg values for the Cleveland-Toledo road run are substantially lower than the other runs, but the ratio changes only slightly.

3.3 Test Vehicle Description

3.3.1 CATEGORY—No background information is required.

3.3.2 VEHICLE SPECIFICATIONS—No background information is required.

3.4 Test Vehicle Weight—The test procedure specifies that the chosen test cycle be run at 100% and 50% of the gross vehicle or combination test weight. The objective of running tests at more than one weight is to determine the variation of mpg with weight. To separate better the weight effect from test to test variability, the test weights should be as different as possible. Testing at 100% of rated gross weight and at empty weight represents the extremes, but empty weight is not consistently the same percentage of rated gross weight. For this reason, a value of 50% of gross test weight was selected.

3.4.1 UNLOADED VEHICLE WEIGHT—No background information is required.

3.4.2 GROSS VEHICLE TEST WEIGHT (GVTW)—No background information is required.

3.4.3 GROSS COMBINATION TEST WEIGHT (GCTW)—No background information is required.

3.4.4 AXLE-BY-AXLE WEIGHT—No background information is required.

Run No.	FE _o × C ₁ × C ₂			mpg Ratios			FE _c : mpg Corrected by Ref. Vehicle Method		
	Veh. 1	Veh. 2	Ref. Veh.	Veh. 1 Ref.	Veh. 2 Ref.	Veh. 2 Veh. 1	Veh. 1	Veh. 2	Ref. Veh.
1	5.825	9.344	6.277	0.928	1.489	1.604	5.634	9.040	6.071
2	5.474	8.860	5.641	0.970	1.571	1.619	5.889	9.538	6.071
3	5.839	9.268	6.105	0.956	1.518	1.587	5.804	9.216	6.071
4	5.714	9.258	6.155	0.928	1.504	1.620	5.634	9.131	6.071
Mean	5.713	9.182	6.044	0.945	1.520	1.608	5.740	9.231	6.071
Std. Deviation	0.169	0.218	0.278	0.021	0.036	0.016	0.127	0.217	
Std. Dev. Mean	3.0%	2.4%	4.6%	2.2%	2.3%	1.0%	2.2%	2.3%	
% Spread	6.4%	5.3%	10.5%	4.4%	5.4%	2.1%	4.4%	5.4%	

3.4.5 and 3.4.6 The gross vehicle weight rating is the preferred maximum vehicle test weight, but in some states the legal loads are less than the rating. For example, a single drive axle rating of 23 000 lb is frequently specified. In the fifty states, this load is legal only in Hawaii. A reduced weight is necessary if the test is to be conducted on public roads.

3.5 Observed Economy—Observed economy is the fuel economy determined during a test cycle by dividing the actual miles driven on the cycle by the measured and uncorrected number of gallons consumed. Economy is expressed as miles per gallon. Fuel consumption is expressed as gallons per mile and is a different parameter. If fuel is measured by weight, the observed fuel economy is the miles travelled divided by the fuel weight converted to gallons using the fuel specific weight determined at 60°F fuel temperature. This corresponds to the volumetric measurement as: Volumetric observed mpg $\times C_2$. Refer to Section 11 of test procedure.

3.6 Corrected Economy—Corrected fuel economy is the observed fuel economy corrected for fuel net heating value and to 60°F fuel temperature. Correction factors for ambient conditions and altitude have not been developed. Additional tests are required to determine the correction factors for the ambient conditions and altitude. To minimize the effect of the ambient temperature, the procedure recommends a rather

narrow temperature band. Barometric pressure effects on aerodynamic drag and engine power (and possibly other factors) at a given test location will normally be too small to be detected outside normal test-to-test variability. Pressure differences due to widely different altitudes affect absolute mpg, but may have little effect on relative fuel economy. No specific limits are set on barometric pressure.

Figs. 4, 5, and 6 show the effect of the various variables influencing the fuel economy. For Fig. 5, 42 points were used to calculate a best fit straight line. Eleven points added later fit the previous data quite well, but alone these eleven points would appear to show a different trend with air temperature. Any future attempts to determine the effect of air temperature for specific vehicles must cover a wide spread of the variable.

Figs. 10, 11, and 12 show the results of a regression analysis on thirty runs of 24,563 miles. Southbound runs were made as well and total fuel for each pair of runs is shown on Fig. 5. There were actually 42 runs, but only thirty had winds which were reasonably consistent for the entire test. Fig. 10 shows that air temperature, air density, and relative velocity squared are all important as single variables. Barometric pressure is not. Fig. 11 shows that relative velocity is more important when air temperature is included and that yaw angle is important only after air temperature and speed squared are included. Fig. 12 shows the complete analysis.

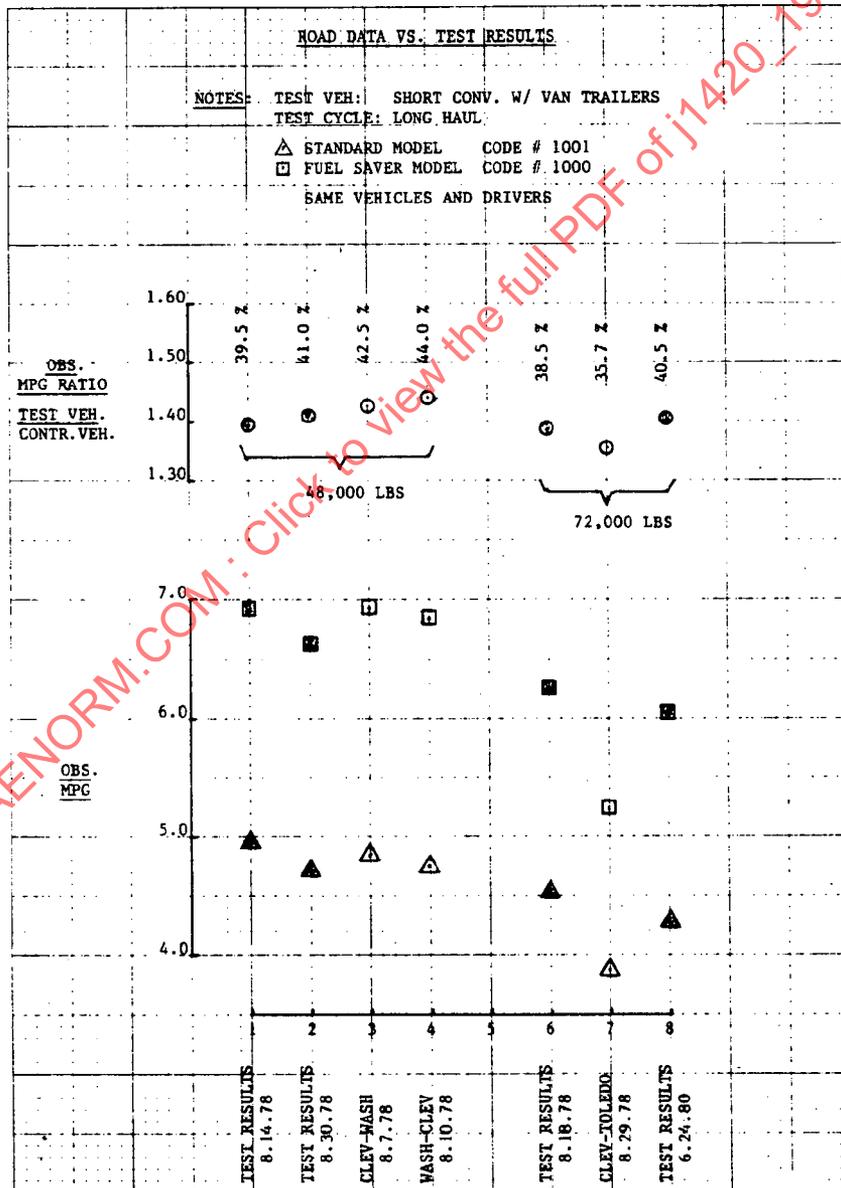


FIG. 2

For equations 29, 34, 22, 39, 19, and 1 in sequence, the coefficients remain relatively unchanged until equation 1 is reached, when large changes occur in all coefficients. Air density is interdependent with temperature and pressure and should not be included. The best equation for this particular set of data is equation 22:

$$\text{Gallons/Trip} = 4.440 - 0.0129 (\text{TA}) + 0.000238 (\text{Rel V})^2 + 0.0201 (\text{yaw angle})$$

for: TA = °F

Rel V = miles per hour

Yaw Angle = degrees absolute

Dividing by 49.126 gives gallons per mile.

3.7 Reference Conditions—No background information is required.

4. Instrumentation—Instruments selected in the performance of the fuel economy tests should be of good quality and be accurate within the prescribed tolerances of the test procedure. The repeatability of the test results depends on instruments that record accurate and consistent test data. Inaccurate instruments will cause a wide variation in the test results.

4.1 The fuel consumption of a vehicle can be measured either by weighing fuel in a portable tank before and after each run or by employing a flow meter. For tests that consume very little fuel, the weighing method is recommended. In applying the weight method, caution should be given in setting up to assure that scales are properly shielded so that gusts of wind will not affect the accuracy of the weight readings. Fuel tanks employed with the weight method should be clean and be equipped with

quick disconnect fittings. Care must be taken not to spill any fuel while connecting or disconnecting the fuel tanks during a test. Fuel temperature at the flow meter or the temperature of the fuel in the tank should be recorded so that the fuel can be corrected to 60°F.

The flow measuring device should be impervious to electrical noise or vibration and should not hinder the vehicle operation or operating characteristics.

4.2 Speed—For vehicle speed measurement, a fifth wheel or the vehicle speedometer can be employed but first it must be calibrated to indicate the vehicle speed within 0.5 mph.

4.3 Acceleration—The maximum acceleration rate of 5 ft/s² was selected to eliminate jack rabbit starts while empty or bobtail.

4.4 Time—No background information is required.

4.5 Temperature—No background information is required.

4.6 Atmospheric Pressure—No background information is required.

4.7 Wind—No background information is required.

4.8 Distance—No background information is required.

4.9 Course Direction—No background information is required.

4.10 Vehicle Weight—No background information is required.

5. Test Material

5.1 Test Vehicle—No background information is required.

5.2 Test Fuel—Fuel analysis is required to establish the fuel net heating value correction factor and to confirm that the fuel conforms to the required specifications. Fuel analysis can be readily obtained at any independent lab. A sample of such analysis is shown in Fig. 3.

F R O M	CLIENT No. <u>1303-001</u> ADVISORY No. <u>138908</u>
	UNIT/N No. <u>Fuel Oil</u> ENGINE SERIAL No. _____
T O	SAMPLE DATE <u>7-12-79</u> DATE TESTED <u>7-26-79</u>
	TYPE SERVICE RENDERED: I-II-III <input type="checkbox"/> OTHER
PHYSICAL TEST RESULTS	
FLASH DEGREES F.: _____	VISCOSITY SSU 100°F.: _____
H ₂ O%: _____	VISCOSITY SSU 210°F.: _____
DETERGENCY _____	ANTI-FREEZE _____
INSOLUBLES NAPHTHA % VOL.: _____	OIL MI/HR.: _____
	ENG. MI/HR.: _____

I ANALYSIS OF PHYSICAL TESTS:

NO CORRECTIVE ACTION INDICATED BY TESTS PERFORMED.

TEST RESULTS INDICATE OIL CONDITION IS SATISFACTORY.

API Gravity at 60°F. = 34.6

Initial IBP = 310°F.

DISTILLATION

90% = 586°F.

Cetane No. = 46.0

10% = 416°F.

End Point = 628°F.

50% = 498°F.

% Return = 98%

II SPECTROCHEMICAL ANALYSIS:

NO CORRECTIVE ACTION INDICATED BY ANALYSIS PERFORMED.

TEST RESULTS INDICATE WEAR METAL LEVELS ARE SATISFACTORY.

Sulfur Content, Bomb Method = 0.40% by wt.

NOTE: Results of tests performed are within #2 Diesel Fuel Oil Specifications.

WHEN CORRECTIVE ACTION IS INDICATED, PLEASE ADVISE RESULTS OF YOUR FINDINGS AND CORRECTIVE ACTION TAKEN ON ENCLOSED POSTCARD.

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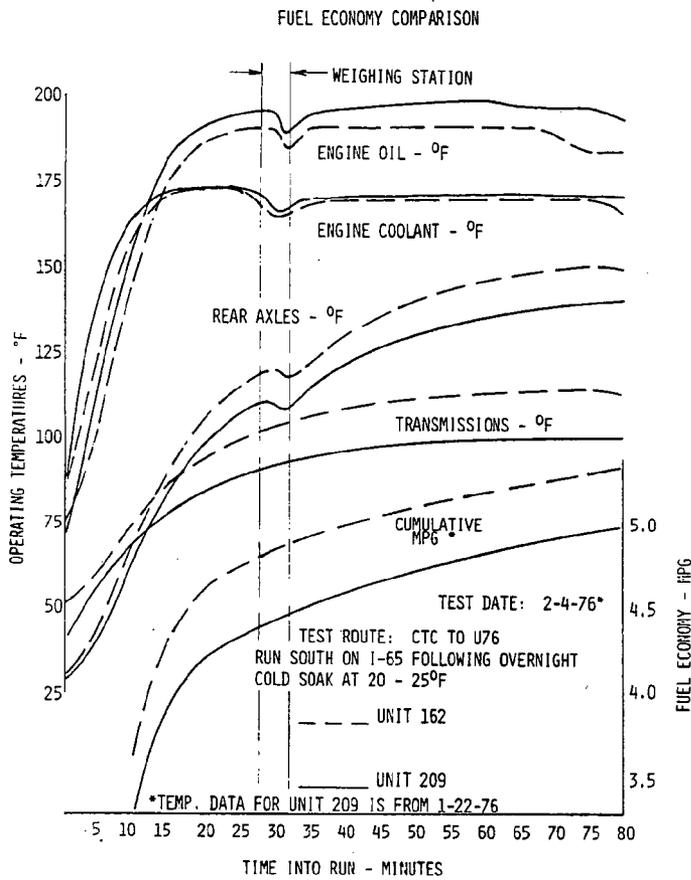


FIG. 4

5.3 Lubricants—No background information is required.

6. Test Conditions—No background information is required.

6.1 Ambient Temperature—Correction factors for ambient temperatures employed in J1082 for passenger cars do not fit the observed changes for trucks. Fig. 5 shows a large air temperature effect for a tractor-trailer employing the long haul test cycle and Fig. 6 shows a small effect for a Class 6 vehicle employing the local test cycle. It is believed that

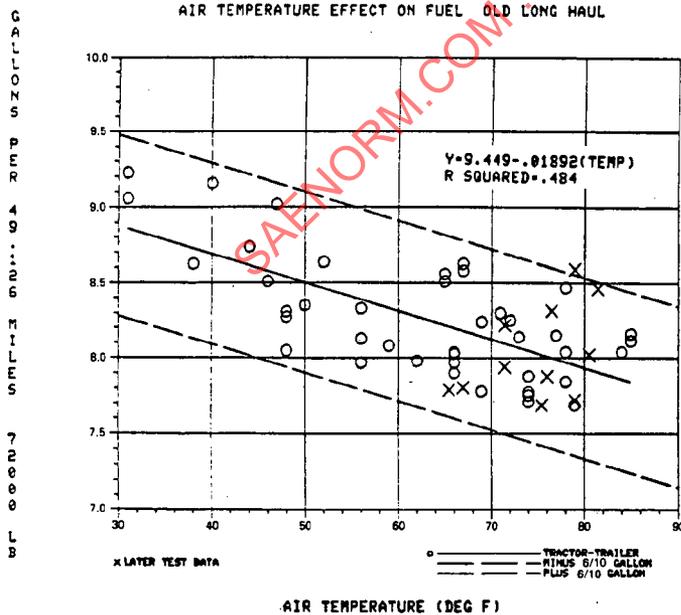


FIG. 5

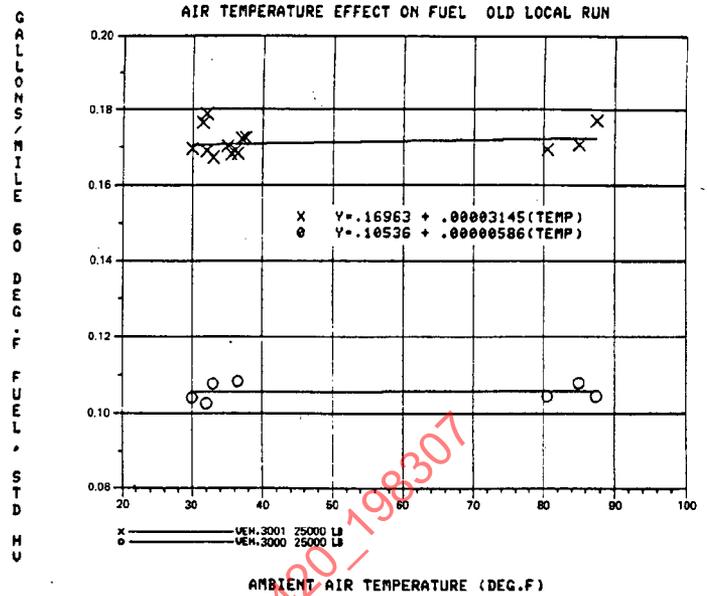


FIG. 6

much of this difference is due to vehicle speeds and aerodynamics effects. The thought has been expressed that vehicles with devices such as clutch drive fans and radiator shutters which respond to temperature probably have different trends in mpg with respect to temperature than vehicles without these devices.

Sufficient test data are not available to establish a correction factor for ambient temperature. For this reason, a rather narrow temperature band of 60-80°F was selected to minimize the ambient temperature effects on the test results.

Fig. 7 shows the differences in the drag coefficients C_d for different class and configuration vehicles as obtained during coast-down tests under favorable conditions. These particular drag coefficient values are based on projected frontal area, not height times width. The calculations necessary to derive them from coast down tests require special knowledge of the tire rolling resistance characteristics. This special data was available for these test vehicles.

6.2 Wind Velocity—Tests must not be conducted when the average wind speed exceeds 15 mph or when wind gusts exceed 20 mph. Lesser wind is desirable. During the development of the test procedure, a limit of 10 mph average wind speed and 15 mph gusts was tried. It was concluded that requiring the lesser wind speeds would greatly reduce the available test periods.

6.3 Road Conditions—In all cases, it is recommended that the tests be conducted on a test track. In cases where a test track is not available, a suitable public highway can be used. It is recommended that the road profile be obtained from a highway department so that the accurate elevation grade and distance of the highway can be determined. Time spent initially in laying out a section of highway for the test will be negligible since in the long run it could be used again and again for future tests.

7. Test Vehicle Specifications—No background information is required.

7.1 Break-In—The 2000 miles for break-in was selected because it is equivalent to the number of hours required to break in the engine and the axles. The break-in is required to minimize the number of variables which affect the repeatability of the test results.

7.2 Inspection—No background information is required.

7.3 Instrumentation—No background information is required.

7.4 Test Weight—No background information is required.

7.5 Tire Pressure—No background information is required.

8. Test Procedure—No background information is required.

8.1 Warm-Up—Test data indicate that one hour of warm-up prescribed in the test procedure is sufficient to stabilize the lubricant temperature of the drivetrain, particularly the axles. Also, cool down of the lubricants starts quite rapidly; therefore, it is recommended that the time between the warm-up and the start of test be kept to a minimum. If for any reason the time period between warm-up and the start of the test is prolonged, the vehicle should be warmed up again for approximately 15 min to stabilize the lube temperatures. Fig. 4 shows the rapid cool-

SAE/DOT TRUCK ROAD COASTDOWN TEST RESULTS

No.	Veh. No.	Veh. Description	Frontal Area—ft ²	Drag Coeff.	Test Weight	Total Road Load at 50 mph	55-45 mph cdt (s)	Average // Wind	Average Wind Dir.	Wind Cond.
1	SAE 1000	Conventional—F.S.	105.0	0.6533	27530 lb	602.87 lb	21.75	0.87 mph	90.8 deg	0-2 mph
2	SAE 1000	Conventional w.o. Wind Deflector	105.0	0.6934	27530 lb	626.98 lb	20.91	0.28 mph	120.8 deg	0-1 mph
3	SAE 1001	Conventional—Std.	105.0	0.9033	27250 lb	803.03 lb	16.28	0.87 mph	141.7 deg	0-2 mph
4	SAE 2000	COE Sleeper—F.S.	106.0	0.7047	29020 lb	639.01 lb	21.95	0.45 mph	116.7 deg	0-1 mph
5	SAE 2001	COE Sleeper—Std.	106.0	0.9781	29140 lb	852.02 lb	16.43	0.51 mph	160.0 deg	0-1 mph
6	SAE 3000	Van Body Truck—F.S.	89.6	0.6806	13220 lb	447.02 lb	14.27	1.19 mph	83.3 deg	0-2 mph
7	SAE 3001	Van Body Truck—Std.	89.6	0.8162	13240 lb	527.87 lb	12.04	1.07 mph	55.0 deg	0-2 mph
8	SAE 4000	Van Body Truck—F.S.	83.7	0.5910	12930 lb	379.46 lb	16.14	1.62 mph	185.0 deg	0-3 mph
9	SAE 4001	Van Body Truck—Std.	83.7	0.6320	12950 lb	423.76 lb	14.39	1.65 mph	182.0 deg	0-3 mph

NOTES:
 Frontal Area: Same values that were used on wind tunnel models; previous testing used different values.
 Test Weight: Vehicles tested unloaded for easier accelerations to stabilization speed.
 Avg. // Wind: Average wind component parallel to direction of vehicle travel; crosswind correction not utilized.
 Avg. Wind Dir.: Relative to the direction of the first pass of the test vehicle.
 F.S.—Fuel Saver Model.
 Std.—Standard Model.

FIG. 7

down of lubricants after the vehicle is stopped at the weighing station and the time required for the lubricant temperatures to stabilize.

- 8.2 Vehicle Controls—No background information is required.
- 8.3 Driving Schedules—No background information is required.

8.3.1 The intent of this test procedure while conducting the tests is to operate the vehicles in the most fuel efficient way. With some vehicles, because of light loads and transmission gearing, a multiple selection of gear choices exists at which the vehicle can be run during a prescribed test cycle. To efficiently operate such a vehicle and to insure that common shift patterns are used for similar tests conducted at different facilities and at different times, the procedure specifies that the lowest available engine rpm be used subject to three gear selection conditions which are prescribed in the test procedure.

- (a) Gear selected for a test element must be able to maintain that speed over the remainder of the test element.
- (b) No gear ratio should be used that will maintain the engine rpm below the engine manufacturer's recommended minimum engine rpm.
- (c) If no engine manufacturer's minimum engine rpm is specified, the gear selected should never operate the engine below 1000 rpm.

The minimum 1000 rpm is an arbitrary number selected to limit the engine rpm to a safe minimum engine speed under full load. Figs. 8 and 9 show the effect of gear selection on fuel economy. Testing at the lowest available engine speed which meets the three criteria listed, will result in engine speeds lower than some drivers prefer, but this specifica-

tion can be used for all types of vehicles, engines, and vocations. This selection of gears will give the best fuel economy for reciprocating engines and future drivers may be motivated to establish new habits. Other proposals were made to establish the gear ratios, but they could not be applied in all cases:

Downshift at rpm of Torque Peak: Not satisfactory for lightly loaded P&D vehicles. Also not satisfactory for some low rpm engines when used with wide step transmissions.

Downshift at a Fixed Percentage of Rated hp rpm: The same percentage is not satisfactory for different engines such as gasoline engines and low rpm diesels.

9. Test Cycles—A representative driving cycle is a key component of the test procedure. Considerable time has been spent in developing the driving cycles. The driving cycles included in this test procedure attempt to represent real world operational characteristics. Factors such as average speed and maximum speed, acceleration rates, idle time, ambient conditions, and vehicle temperature stabilization are known to significantly influence fuel economy and they have been addressed in developing the driving cycles. For a detailed history in the development of the driving cycles, refer to SAE Paper 831784, Development of Fuel Economy Test Procedures by Richard S. Johnson, presented at the 1983 Truck and Bus Meeting and Exposition, November 7-10, 1983.

The driving cycles should be repeated several times to assure repeatability of the test results. The number of times the cycles should be repeated is left to the judgement of the individual performing the tests, but a minimum of three tests is required. The repeatability of the mpg ratio from test to test is an important tool to detect errors in the test results and to determine the number of times the test should be repeated.

EFFECT OF GEAR RATIO (AVERAGE RPM) ON FUEL

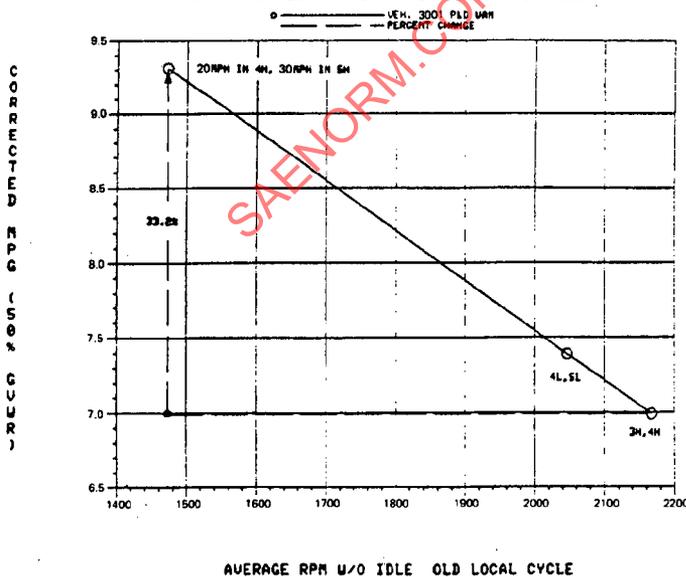


FIG. 8

EFFECT OF GEAR SELECTION ON FUEL ECONOMY

Engine/Transmission Schedule	Gasoline (mpg)		Diesel (mpg)	
	3001	4001	3000	4000
Low rpm	8.13	5.31	13.93	9.47
Moderate rpm	6.47	3.84	11.34	6.54
High rpm	4.69	3.17	8.20	4.96

FIG. 9A

FUEL CONSUMPTION IMPROVEMENT WITH LOW RPM ENGINE/TRANSMISSION SCHEDULE

Engine/Transmission Schedule	% Improvement			
	3001	4001	3000	4000
Moderate to low	20	28	19	31
High to low	42	40	41	48

FIG. 9B