

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1376

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Fuel Economy Measurement Test (Engineering Type) for Trucks and Buses

1. Scope—This procedure incorporates test cycles that produce relative fuel economy data relating to long haul, short haul, and local driving patterns, or any combination of these and to those components developed to improve fuel economy for these patterns. The tests conducted on a specific vehicle are to reflect that vehicle's general mode of operation. The procedure is intended to be used under controlled, warmed-up conditions on a test tract or on suitable roads. A minimum of two vehicles running simultaneously is required. Test condition recommendations are provided for undertaking this engineering test. If it is necessary to conduct a test outside of these test conditions, the purpose of the test and the variant conditions should be recorded and noted whenever the results are reported.

1.1 Purpose—To provide uniform testing procedures for measuring relative fuel economy of trucks and buses over 10 000 lb GVWR.

1.1.1 OVERVIEW—The objective of this test procedure is to provide the user with a standard test procedure for evaluating the relative fuel economy of given vehicles. The test procedure employs test cycles which reflect different modes of vehicle operation and provides the basis for evaluating the effects of those modes on fuel economy of the vehicle. The fuel can be measured either by weight or by volume. Fuel economy is expressed in mpg.

The test procedure requires a control vehicle to be run simultaneously with the test vehicle on the same course and at the same time. The assumption is made that during a test both vehicles are affected by the ambient conditions in the same manner. The ratios of the mpg values of the control vehicle and the test vehicle should remain relatively constant regardless of the mpg variations from test to test. This ratio is applied in calculating the test results and for spotting errors while in the process of conducting the tests.

Correction factors applied to the observed mpg values are for standard fuel heating value and standard 60 °F fuel temperature. Correction factors for barometric pressure and ambient temperature are not available. The ambient temperature has a pronounced effect on the fuel economy; therefore, to minimize the effect the procedure recommends a rather narrow temperature range for conducting the tests.

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2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1210—Medium and Heavy Duty Truck and Bus Categorization System

2.1.2 TIRE AND RIM ASSOCIATION PUBLICATION—Tire and Rim Association, 175 Montrose West Avenue, Suite 150, Copley, OH 44321.

Tire and Rim Yearbook

3. Definitions

3.1 Test Cycles

3.1.1 LONG HAUL CYCLE—The driving pattern defined by 9.1 and Figure 1 reflects interstate highway operation and provides a basis for evaluating those components affecting steady-state high speed fuel economy.

TOTAL DISTANCE 30 MILES
TOTAL IDLE 180 SEC.

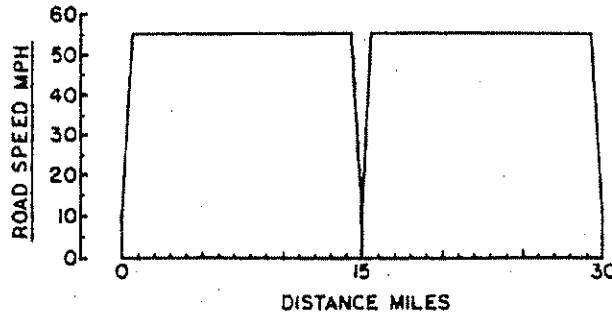


FIGURE 1—LONG HAUL TEST CYCLE

3.1.2 SHORT HAUL CYCLE—The driving pattern defined by 9.2 reflects inter- and intra-city operation and provides a basis for evaluating those components affecting acceleration, deceleration, and steady-state-speed fuel economy.

3.1.3 LOCAL CYCLE—The driving pattern defined by 9.3 reflects intra-city operation (pick-up and delivery) and provides a basis for evaluating those components affecting stop and go fuel economy.

3.1.4 TRANSIT CYCLE—The driving patterns defined by 9.4 reflect those published by DOT and UMTA as the Baseline Advanced Design Transit Coach Specification, Part II, paragraph 1.2 (17), Procurement Document for New 30 and 40 Foot Coach Designs.

3.2 Test Vehicle—Truck, truck-tractor, bus, or motor home with GVWR over 10 000 lb prepared for test per Section 7.

3.2.1 **MODEL IDENTIFICATION**—Test vehicles shall be identified by manufacturer's name, model year, series/model, and GVW or GCW rating.

3.2.2 **COMPONENT IDENTIFICATION**—All vehicle components requiring identification on the Test Vehicle Specification Sheet shall be entered as indicated on this sheet.

3.2.3 **CONTROL VEHICLE**—A control vehicle is used to measure variability associated with a specific test course caused by changes from time period to time period of such factors as wind speed and direction, ambient temperature, humidity, etc., beyond practical control. A preferred control vehicle is of such configuration that the above mentioned variables will generally be expected to affect the control vehicle and test vehicle in a similar fashion. Attention must be placed on maintaining and operating the control vehicle in such a manner that if the aforementioned variables did not exist, identical results would be obtained each time the same test cycle was run.

3.3 Test Vehicle Description

3.3.1 **CATEGORY**—The category of the test vehicle as defined by SAE J1210, Medium and Heavy Duty Truck and Bus Categorization System. (NOTE: Tractors, when tested in combination with trailers, may have more than one category and require more than one testing basis.)

3.3.2 **VEHICLE SPECIFICATIONS**—The itemization of pertinent data about the test vehicle as defined by Section 10, Data Recording.

3.4 Test Vehicle Weights

3.4.1 **UNLOADED VEHICLE WEIGHT**—The weight of the vehicle with maximum capacity of all fluids necessary for operation of the vehicle including fuel. For transit buses, this weight is defined as Unseated Passenger Weight.

3.4.2 **GROSS VEHICLE TEST WEIGHT (GVTW)**—Unloaded vehicle weight plus the payload necessary to reach maximum vehicle test weight (refers to trucks). For transit buses, this test weight is defined as Seated Passenger Weight.

3.4.3 **GROSS COMBINATION TEST WEIGHT (GCTW)**—Unloaded vehicle and trailer(s) weight plus payload to reach maximum combined test weight.

3.4.4 **AXLE BY AXLE WEIGHT**—Scale weight of each individual axle. No axle should be loaded in excess of its rating.

3.4.5 The maximum vehicle test weight is (1) the gross vehicle weight rating (GVWR) of the vehicle or (2) the maximum legal load at the test location, whichever is lower.

3.4.6 The maximum combination test weight is (1) the gross combination weight rating (GCWR) of the vehicle and trailer(s) or (2) the maximum legal load at the test location, whichever is lower.

3.5 Observed Economy—The fuel economy is determined during a test cycle by dividing the actual miles driven on the cycle by the measured and uncorrected number of gallons of fuel 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 traveled 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.

3.6 Corrected Economy—Corrected economy is the observed economy adjusted by the corrections listed in Section 11.

3.7 Reference Conditions—Standard ambient conditions of 70 °F and 29.00 in Hg. The reference temperature lies halfway between test temperature limits of 60 and 80 °F.

4. Instrumentation—All instrumentation shall be calibrated per manufacturer's specifications.

4.1 Fuel—Volumetric fuel measurement system must be compatible with the vehicle fuel system and shall alter the fuel temperature and pressure as little as possible. The fuel measuring device must be accurate within 0.5% of the actual fuel consumption. Fuel temperature through a volumetric fuel measuring device should be recorded.

Fuel consumption can also be measured by weighing the fuel at the start and finish of each test. The fuel temperature shall be recorded after each test. Fuel employed in the test should be contained in a tank equipped with leak proof quick disconnect fittings. Scales employed in weighing the fuel shall be calibrated and be capable of being read to the nearest 0.5 oz.

4.2 Speed—The speed indicating device shall indicate vehicle speed in miles/hour and be accurate within 0.5 mph.

4.3 Acceleration—The acceleration indicating device must be capable of indicating both positive and negative acceleration. It shall indicate acceleration/deceleration in feet/second² and be accurate within 0.5 ft/s².

4.4 Time—The time measuring instrument must be capable of measuring time interval to 0.5 s and be accurate within 0.5 s in 1 h.

4.5 Temperatures—The temperature indicating device must be capable of being read to the nearest 2 °F. Accuracy must be within 2 °F. The sensing element shall be shielded from radiant heat sources. Wet bulb temperature and dry bulb temperatures are to be recorded.

4.6 Atmospheric Pressure—An aneroid or mercury barometer should be used. This device should be accurate within 0.1 in Hg.

4.7 Wind—Wind speed should be measured at the test location with a device which provides an indication of wind speed that is accurate within 2 mph between 4 and 20 mph. Wind direction should be indicated in a 16 point (360 deg) compass reading.

4.8 Distance—A distance-indicating device is required if the tests are not conducted on a premarked course. This device must be capable of indicating distance to within 0.5% of the course distance.

4.9 Course Direction—Course direction will be determined by drawing a line from the beginning to end of the test course or test leg.

4.10 Vehicle Weight—Vehicle weight should be measured with a device that is accurate within 1.0%. Resolution should be 50 lb or less.

5. Test Material

5.1 Test Vehicle—The test vehicle shall be completely defined as specified on the Test Vehicle Specification Sheet and Test Vehicle Preparation Sheet. (See Appendices A and B.)

5.2 Test Fuel—Normally, service station fuel will be satisfactory for test purposes. The specific gravity of the fuel at 60 °F (referred to water at 60 °F) and the Reid vapor pressure should be recorded. The 50% distillation temperature is also needed for diesel fuel. Grades of fuel, as specified by engine manufacturer, shall be used.

- 5.3 **Lubricants**—Lubricants used shall conform to the manufacturer's recommendation for the predominant weather condition in which the vehicle is being tested.

6. *Test Conditions*

- 6.1 **Ambient Temperature**—Tests should be conducted at ambient temperatures between 60 and 80°. Temperatures outside of this range shall be noted on the Test Vehicle Data Sheet and reported with the fuel economy values.
- 6.2 **Wind Velocity**—Tests must not be conducted when average wind speed exceeds 15 mph or when gusts exceed 20 mph.
- 6.3 **Road Conditions**—Roads used should be surveyed and must be dry, clean, and smooth. The maximum change in elevation throughout the course should not exceed ± 150 ft in one mile. The maximum grades must be such that the vehicle can be operated within the speed variations specified in 8.3.1.6 while in the same gear ratio that would be used for the specified test element on level road.
- 6.4 It is recommended that roadside markers be used to indicate the points at which speed changes are to be made, as indicated in Section 9.
- 6.5 Total course distance to be within 2% of that as defined by the driving schedule.

7. *Test Vehicle Specification*

- 7.1 **Break-In**—The vehicle should have accumulated a minimum of 2000 miles of operation prior to the test. At least 1000 miles must have been driven at cycling speeds between 40 mph and maximum legal highway speeds. If a closed track is available for break-in, the maximum speed should not exceed 70 mph. Chassis dynamometer break-in is acceptable, providing the tires have operated at least 100 miles under load prior to the test.
- 7.2 **Inspection**—The vehicle must be inspected including, if possible, a chassis dynamometer power test. Fuel rate at governed or maximum speed at wide open throttle should be ascertained and adjusted where necessary to meet manufacturer's specifications. These inspections include wheel alignment and brake release. Checks are specified on the Test Vehicle Preparation Sheet.
- 7.3 **Instrumentation**—The fuel measuring device and other instrumentation, as necessary, must be installed in such a manner as not to hinder the vehicle operation or operating characteristics.
- 7.4 **Test Weight**—The vehicle weight must be adjusted to provide the test weight indicated in 9.1, 9.2, 9.3, and 9.4. (This test weight includes instrumentation and operator.)
- 7.5 **Tire Pressure**—The inflation pressure of each tire must be measured cold and should be adjusted to the value specified in the current Yearbook of the Tire and Rim Association, for either the gross axle rating or the gross tire rating, whichever is lower. This pressure should not exceed the maximum tire rating.

NOTE—As specified in 3.4.4, no axle should be loaded beyond the Gross Axle Weight Rating (GAWR).

8. *Test Procedure*

- 8.1 **Warm-Up**—The vehicle should be driven a minimum of 1 h at approximately 55 mph or maximum legal highway speed to stabilize engine and drivetrain operating temperatures before running the first test cycle.

CAUTION: The time interval between warm-up and start of the test should be held to a minimum.

8.2 Vehicle Controls

- 8.2.1 Air conditioner compressor, headlamps, and other accessories that consume power should be in the same mode for both vehicles, preferably in the turned off condition unless required for safe vehicle operation, except for a specific component under evaluation.

NOTE—The air conditioner compressor operates when some defroster systems are on.

- 8.2.2 It is preferable that vehicle windows remain closed while fuel consumption is being measured during the long haul, short haul, and transit cycles. If this is not the case, it should be recorded.
- 8.2.3 Care should be taken that accessories for both vehicles are in the same mode and these data are recorded.
- 8.2.4 To minimize the effects of driver skills on the test results, it is recommended that drivers should be utilized in the following manner:
- 8.2.4.1 *Control Vehicle*—The control vehicle should be driven by the same driver throughout the test period.
- 8.2.4.2 *One Control Vehicle—One Test Vehicle*—If only one test vehicle is used and components are changed on the vehicle, then only one driver is required for that vehicle. In this instance, the effect of the driver is the same with and without test component.
- 8.2.4.3 *One Control Vehicle—Two or More Test Vehicles*—Normally, each vehicle should be driven by the same test driver. Ratios of test/control vehicle mpg may be compared only for configuration changes made on the same vehicle with the same driver on the same route. Only one of these three elements should be changed at a time. The effect of different drivers should be treated in the same manner as a configuration or a test cycle change and a complete duplicate series of tests should be run.

8.3 Driving Schedules

8.3.1 GENERAL DRIVING INSTRUCTIONS

- 8.3.1.1 Vehicle(s) incapable of attaining speed or acceleration rates specified by the test cycles will be driven at maximum attainable speed until the next maneuver point is reached. Note on Data Form any departure from the specified cycle. (See Appendix C.)
- 8.3.1.2 Vehicle(s) equipped with automatic transmission should be driven with the transmission in "drive" range, unless this is contrary to the manufacturer's recommendation for the type of service represented by the test cycle, in which case the manufacturer's recommended procedure should be used and so noted on the Test Vehicle Data Sheet. If transmission "hunting" should be encountered at a specified speed, the lower range should be selected to maintain the vehicle speed and this departure from the schedule noted on the Test Vehicle Data Sheet. During deceleration, the throttle is to be closed and the transmission is to remain in the same position that it was in when deceleration began.
- 8.3.1.3 Vehicle(s) equipped with manual transmission will be operated in the following manner. Starting from rest, the deepest normal highway starting gear recommended by the manufacturer of the vehicle, as equipped and loaded, will be selected. During the acceleration mode of any element, gear ratios selected should be those that produce a positive acceleration after making the upshift. Upshifts should be made at the manufacturer's recommended maximum rated engine speed in each gear. Upon reaching the speed at which the vehicle will be driven at constant speed, the gear ratio selected will be the one which will produce the lowest engine rpm but which will also allow:

- a. Vehicle speed to be maintained constant over the remainder of the test element.
- b. If the engine manufacturer recommends a minimum operating rpm, no gear should be used which results in operating the engine below this rpm.
- c. If a minimum operating rpm is not specified by the manufacturer, it is recommended that the engine not be operated at less than 1000 rpm.

During decelerations, the throttle will be closed, the transmission will remain in gear, and the clutch will be disengaged when the vehicle speed reaches 5 mph or the engine speed reaches 700 rpm, whichever comes first.

- 8.3.1.4 Test vehicle(s) are to be run against the control vehicle for fuel economy improvement data generation. The vehicles must be tested concurrently, but should not aerodynamically interfere with each other.
- 8.3.1.5 The vehicle(s) are to be accelerated at W.O.T. (wide open throttle) not to exceed 5 ft/s^2 and acceleration rate is to be monitored unless otherwise prescribed by the test cycle.
- 8.3.1.6 During the constant speed elements of any test cycle, the speed shall be maintained within ± 3 mph of the required speed. The average speed of the constant speed portion of the test must be within ± 1 mph of the average speed specified for the cycle (except as noted in 8.3.1.1).
- 8.3.1.7 The vehicle(s) deceleration is to be initiated by coasting in gear with subsequent brake application to produce the speed change within the given course length of the test cycle. The test cycles are based on an average of 3 ft/s^2 deceleration rate of combined coasting and braking.
- 8.3.1.8 The fuel measurement by weight or volume shall be taken from the start of any test cycle until the end of that test cycle. Exceptions to this procedure are to be noted on the Test Vehicle Data Sheet. (Turnaround fuel, distance, and time are to be excluded.)

9. **Test Cycles**—Test cycles are described in 9.1, 9.2, 9.3 and 9.4. Vehicles should be tested a sufficient number of times utilizing the following cycles to meet the criteria defined in 11.5.4. If multiple test segments are conducted before turnaround, data for each segment in the first direction should be paired to corresponding test segments in the return direction.

NOTE—The distance, fuel consumed, and elapsed time for turnaround maneuvers are not to be included in the test cycle results. Turnaround is not required on closed loop test tracks.

9.1 Long Haul at 100% and 50% GVTW (see 3.4 and Table 1)

TABLE 1—LONG HAUL TEST CYCLE FIGURE 1

Element	Maneuver	End Point Distance (ft)
0	Start Engine	0
1	Acc to 55 mph (Full throttle)	—
2	Cruise at 55 mph	78 115
	Coasting Deceleration	—
3	Braking Dec to 0 mph	79 200 (15 miles)
4	Acc to 55 mph (Full throttle)	—
5	Cruise at 55 mph	157 315
6	Coasting Deceleration	—
7	Braking Dec to 0 mph	158 400 (30 miles)
8	Idle 180 s	
9	Turn Off Engine	
10		

If track is not closed loop, conduct elements 5–8 in opposite directions from 1–4, allowing for turnaround.

Total distance - 30 miles.

A minimum of three separate tests should be run.

9.2 Short Haul at 100% and 50% GVTW (see 3.4)—Test cycle 9.2.1 is the preferred short haul test cycle and should be used if a suitable test track is available. Test cycle 9.2.2 is more readily adaptable to the public highways if a suitable test track is not available. A minimum of three separate tests should be run.

9.2.1 PREFERRED SHORT HAUL TEST CYCLE (SEE TABLE 2 AND FIGURE 2):

TABLE 2—PREFERRED SHORT HAUL TEST CYCLE

Element	Maneuver	End Point, Distance (ft)
0	Start Engine	—
1	Acc to 10 mph (1/2 Throttle)	—
2	Acc to 25 mph (Full Throttle, All remaining accels)	—
3	Cruise at 25 mph	2640
4	Acc to 30 mph	—
5	Cruise at 30 mph	5280
6	Acc to 35 mph	—
7	Cruise at 35 mph	10 560
8	Acc to 40 mph	—
9	Cruise at 40 mph	18 480
10	Acc to 45 mph	—
11	Cruise at 45 mph	26 400
12	Acc to 50 mph	—
13	Cruise at 50 mph	34 320
14	Acc to 55 mph	—
15	Cruise at 55 mph	38 515
16	Coasting Dec-Dec to 15 mph	—
17	Braking Dec to 0 mph	39 600
18	Idle 60 s	—
REPEAT ONE TIME		
19	Turn Off Engine	—

Total distance - 15 miles.

If track is not closed loop, conduct repeat of elements 1–18 in opposite direction allowing for turnaround.

RUN 2 TIMES
TOTAL DISTANCE 15 MILES
TOTAL IDLE 120 SEC

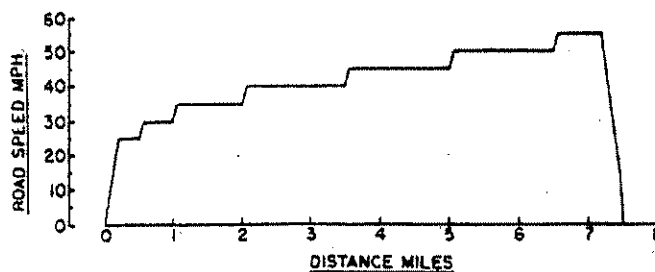


FIGURE 2—SHORT HAUL TEST CYCLE

9.2.2 SHORT HAUL TEST CYCLE WITHOUT SUITABLE TEST TRACK (SEE TABLE 3 AND FIGURE 3):

TABLE 3—SHORT HAUL TEST CYCLE WITHOUT SUITABLE TEST TRACK

Element	Distance at End. Miles	Speed, mph	Idle time, s	Mode of Operation
0	0	0	—	Start Engine
1	0	0	60	Low idle in gear
2	D	0-25	—	Accelerate to 25 mph
3	5.0	25	—	Constant Speed
4	D	25-35	—	Accelerate to 35 mph
5	10.0	35	—	Constant Speed
6	D	35-55	—	Accelerate to 55 mph
7	14.80	55	—	Constant Speed
8	15.0	55-0	—	Decelerate to 0 mph
9	15.0	0	60	Low idle in gear
10	15.0	0	—	Turn Off Engine

Run elements 1-9 two times (one time in each direction).

Reference 11.5.4. Turnaround is not included (except for closed loop test track).

Total distance - 30 miles.

Idle time - 240 s.

D = Distance required to accelerate to maximum speed indicated.

RUN 2 TIMES
TOTAL DISTANCE 30 MILES
TOTAL IDLE 240 SEC.

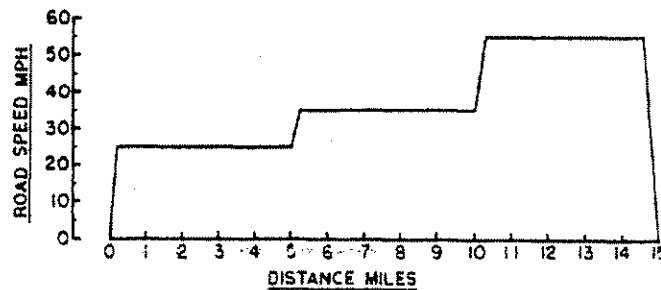


FIGURE 3—SHORT HAUL TEST CYCLE

9.3 Local at 100% and 50% GVTW (see 3.4):—Test cycle 9.3.1 is the preferred local test cycle and should be used if a suitable test track is available. Test cycle 9.3.2 is more readily adaptable to the public highways if a suitable test track is not available.

A minimum of three separate tests should be run.