FEDERAL TRANSIT BUS TEST

Performed for the Federal Transit Administration U.S. DOT
In accordance with 49 CFR, Part 665

Altoona Bus Testing and Research Center
Test Bus Procedure

6. FUEL ECONOMY TEST – A FUEL CONSUMPTION TEST USING AN APPROPRIATE OPERATING CYCLE

Pass/Fail
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ABBREVIATIONS

ABTC	Altoona Bus Test Center
A/C	Air Conditioner
ADB	Advance design bus
CBD	Central business district
CI	Compression ignition
CNG	Compressed natural gas
CW	Curb weight (bus weight including maximum fuel, oil, and coolant; but without passengers or driver)
dB(A)	Decibels with reference to 0.0002 microbar as measured on the "A" scale
DIR	Test director
DR	Bus driver
EPA	Environmental Protection Agency
FFS	Free floor space (floor area available to standees, excluding ingress/egress areas, area under seats, area occupied by feet of seated passengers, and the vestibule area)
FTA	Federal Transit Administration
GAWR	Gross axle weight rating
GL	Gross load (150 lb. for every designed passenger seating position, for the driver, and for each 1.5 sq. ft. of free floor space)
GVW	Gross vehicle weight (curb weight plus gross vehicle load)
GVWR	Gross vehicle weight rating
hr.	Hour
LNG	Liquefied natural gas
LTI	Larson Transportation Institute
mpg	Miles per gallon
mph	Miles per hour
NBM	New bus models
PSTT	Penn State Test Track
rpm	Revolutions per minute
SAE	Society of Automotive Engineers
SCF	Standard cubic feet
SCFM	Standard cubic feet per minute
SCH	Test scheduler
SA	Staff Assistant
SI	Spark ignition
SLW	Seated load weight (curb weight plus 150 lb. for every designated passenger seating position and for the driver)
TD	Test driver
TM	Track manager
TP	Test personnel

6-I. TEST OBJECTIVE

The objective of this test is to provide accurate comparable fuel consumption data on transit buses produced by different manufacturers. This fuel economy test bears no relation to the calculations done by the Environmental Protection Agency (EPA) to determine levels for the Corporate Average Fuel Economy Program. EPA's calculations are based on tests conducted under laboratory conditions intended to simulate city and highway driving. This fuel economy test, as designated here, is a measurement of the fuel expended by a vehicle traveling a specified test operating profile, under specified operating conditions that are typical of transit bus operation. The results of this test will not represent actual mileage, but will provide data that can be used by FTA Grantees to compare buses tested using this procedure.

6-II. TEST DESCRIPTION

This test is performed in the emissions bay of the LTI Vehicle Testing Laboratory. The Laboratory is equipped with a Schenk Pegasus 300 HP, large-roll (72 inch diameter) chassis dynamometer suitable for heavy-vehicle emissions testing. The dynamometer is located in the end test bay and is adjacent to the control room and emissions analysis area. The driving cycles are the Manhattan cycle, a low average speed, highly transient urban cycle (Figure 1), the Orange County Bus Cycle which consists of urban and highway driving segments (Figure 2), and the EPA HD-UDDS Cycle (Figure 3).). A fuel economy test will comprise of two runs for the three different driving cycles, and the average value will be reported.

1. For liquid fuels, this test procedure uses a calibrated flowmeter system and/or a calibrated fuel weighing scale. The flowmeter system utilizes a precise four-piston positive displacement flow meter. The weighing scale system includes heat exchangers to maintain temperature in diesel and common-rail injection systems.

2. For gaseous fuels, like compressed natural gas (CNG), liquefied natural gas (LNG), cryogenic fuels, and other fuels in the vapor state, a calibrated gaseous flowmeter will be used to determine the fuel consumption. The pressure and temperature across the flow element will be monitored by the flow computer. The flow computer will use this data to calculate the gas flow rate. The flow computer will also display the flow rate (scfm) as well as the total fuel used (scf). The total fuel used (scf) for each test will be recorded on the Fuel Economy Data Form.

6-III. TEST ARTICLE

The test article is a transit bus with a minimum service life of 4, 5, 7, 10 or 12 years.

6-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

NOTE: A fire extinguisher must be present during testing.

Testing is performed in the LTI Vehicle Testing Laboratory emissions testing bay. The test bay is equipped with a Schenk Pegasus 72-inch, large-roll chassis dynamometer. The dynamometer is electronically controlled to account for vehicle road-load characteristics and for simulating the inertia characteristics of the vehicle. Power to the roller is supplied and absorbed through an electronically controlled 3-phase ac motor. Absorbed power is fed back onto the electrical grid.

A. The following describes the equipment used for diesel, gasoline, methanol, and any other fuel in the liquid state (excluding cryogenic fuels).

A calibrated fuel weighing scale or a calibrated fuel flow meter is used to measure the fuel consumption. A stainless steel drum of 20 gallons capacity with a lift pump and provision for fuel supply and return lines will be used for weighing the fuel consumed during a test. This system includes heat exchangers to ensure the fuel temperature does not exceed 100 F during tests. The fuel flow measurement system calculates fuel flow based on the known displacement of four precision engineered cylinders. Hall sensors located around the crankshaft transform each piston stroke into a pulse signal proportional to fuel consumption. A data acquisition computer is used to convert the Hall sensors signals to gallons of fuel used. A digital display is mounted on the windshield to display fuel used and test time. A thermocouple is placed in line with the fuel from the tank. The system consists of the following instruments:

1. Corrsys-Datron DFL-2 Fuel Flow Meter (Gasoline)
2. Corrsys-Datron DFL-3 Fuel Flow Meter (Diesel)
3. Corrsys-Datron DAQ computer or Stand Alone Display
4. Sartorious Scale and fuel pump.
5. Thermocouple and digital display

B. The following describes the equipment used for CNG, LNG, cryogenic fuels or any other fuel that is stored in the vapor state.

The methods for storing CNG and LNG on-board a vehicle are vastly different. CNG is stored as a very high pressure gas, and LNG as a cryogenic liquid. These differences and the safety considerations associated with handling the stored fuels render gravimetric measurement systems for CNG and LNG impractical.

Although their methods of storage are quite different, both CNG and LNG systems deliver the fuel to the engine in the vapor state. This procedure exploits this commonality between the two systems by using a flow measurement device in series with the fuel line, just prior to delivery to the engine. The flow measurement system uses a computer to compensate for pressure and temperature variations. The system consists of the following important components:

1. Gas Flow Meter
2. Flow Computer
3. Integrated RTD Temperature Sensor

C. The following describes test equipment used for electric vehicles.

The batteries of the electric bus will be charged from a low SOC to gull. A 3-phase power meter is connected to the wires that feed the charger from the outlet. When the batteries charge, the energy input (kWh) at different SOCs (in steps of 5) are noted so that a trace of SOC versus kWh can be generated. The bus is then secured to the chassis dyno and the fuel economy tests as described above will be conducted. The SOC at the beginning and end of each test cycle is noted. The energy (kWh) consumed for each test is determined from the SOC versus kWh trace.

6-V. TEST DATA

The fuel economy test is performed in the LTI Vehicle Testing Lab. This test requires the following personnel:

1. Test driver (TD)
2. Test Personnel (TP)

6-VI. TEST PREPARATION AND PROCEDURES

All vehicles are prepared for testing in accordance with the Fuel Economy Pre-Test Maintenance Form. This is done to ensure that the bus is tested in optimum operating condition. The manufacturer-specified preventive maintenance shall be performed before this test. Any manufacturer-recommended changes to the pre-test maintenance procedure must be noted on the revision sheet. The Fuel Economy Pre-Test Inspection Form will also be completed before making a test run. Both the Fuel Economy Pre-Test Maintenance Form and the Fuel Economy Pre-Test Inspection Form are found on the following pages. All forms must be completed using a pen.

All buses are tested at SLW. The fuel economy data are obtained at the following conditions:

1. Air conditioning off
2. Seated load weight during coast down
3. Exterior and interior lights on
4. Defroster off
5. Windows and Doors closed

Coast down test will be conducted prior to securing the bus on the chassis dynamometer. The data from the coast down test will be used to simulate the road load of the test bus at different speeds.

The test tanks or the bus fuel tanks(s) will be filled prior to the fuel economy test with the appropriate grade of test fuel. Warm-up consists of driving the bus for 20 minutes at approximately 40 mph on the chassis dynamometer. The test driver follows the prescribed driving cycle watching the speed trace and instructions on the Horiba Drivers-Aid monitor which is placed in front of the windshield. The CDCTS computer monitors driver performance and reports any errors that could potentially invalidate the test. After the cycle is complete, the total fuel used will be recorded on the Fuel Economy Data Form.

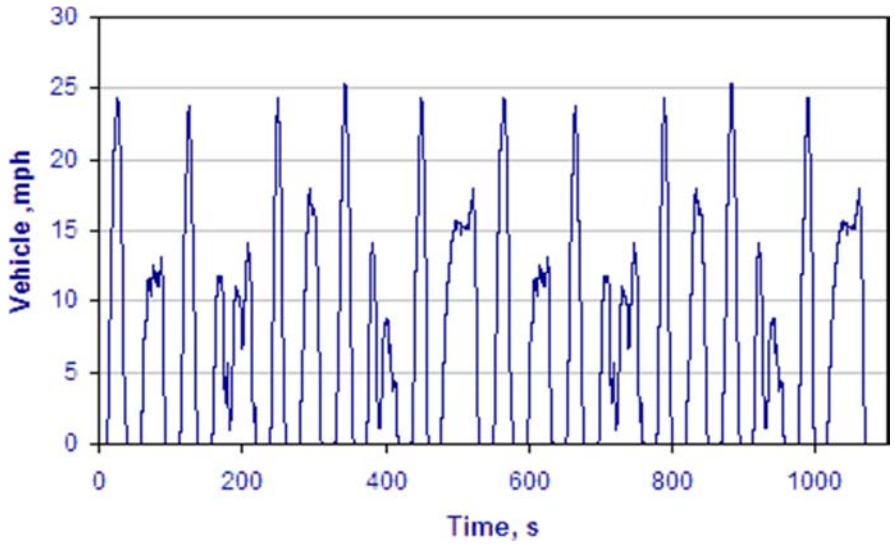

Figure 1. Manhattan Driving Cycle (duration 1089 sec, Maximum speed 25.4 mph, average speed 6.8 mph)

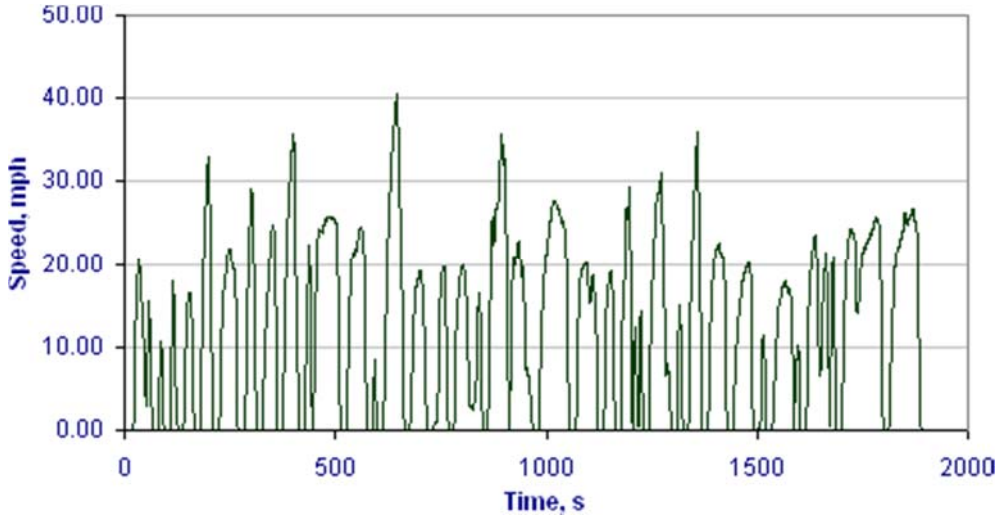

Figure 2. Orange County Bus Cycle (Duration 1909 Sec, Maximum Speed 41 mph, Average Speed 12 mph).

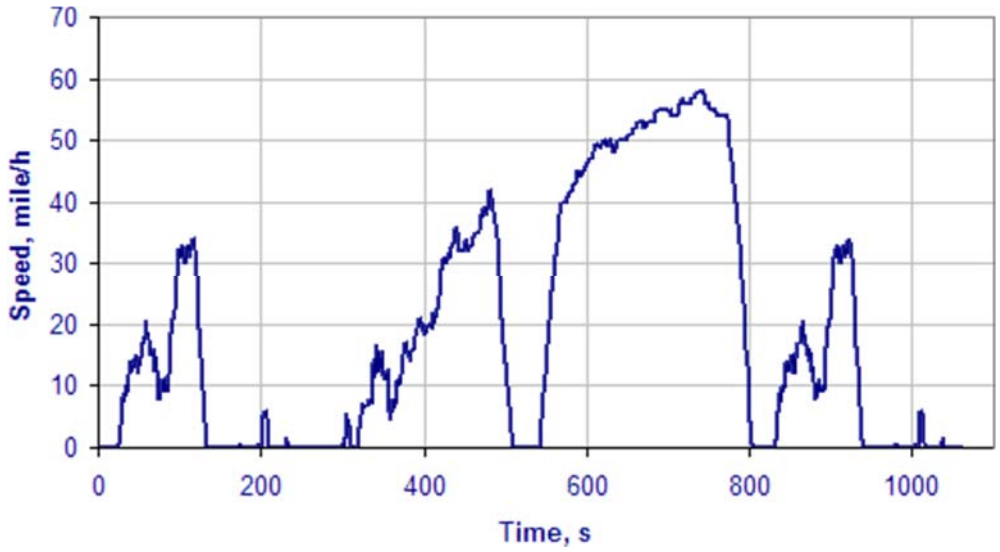

Figure 3. HD-UDDS Cycle (duration 1060 seconds, Maximum Speed 58 mph, Average Speed 18.86 mph).