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. ENERGY ECONOMY TEST – AN ENERGY CONSUMPTION TEST FOR BATTERY ELECTRIC BUSES USING APPROPRIATE OPERATING CYCLES

Pass/Fail
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ABBREVIATIONS

ABTC	Altoona Bus Test Center
A/C	Air Conditioner
ADB	Advance design bus
AC	Alternating current
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
DC	Direct current
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
Wh	Watt hour

6-I. TEST OBJECTIVE

The objective of this test is to provide accurate comparable energy consumption data on battery electric 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 energy economy test, as designated here, is a measurement of the energy consumed 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).).

This test is conducted generally as per the methods described in the SAE standard J 1634-2017. The light-duty test cycles specified in this standard are replaced by transit bus test cycles mentioned above. A Single-Cycle Test (SCT) or a Multi-Cycle Test (MCT) is chosen depending on the range of the bus. The following test sequence is adopted for a Multi-Cycle test (MCT) with the test starting with a fully charged battery system.

1. HD-UDDS cycle
2. Manhattan cycle (2 cycles, back to back)
3. Orange County Bus Cycle
4. HD-UDDS cycle
5. SS65: constant speed cycle at 65 mph
6. HD-UDDS cycle
7. Manhattan cycle (2 cycles, back to back)
8. Orange County Bus Cycle
9. HD-UDDS cycle
10. SS65: constant speed cycle at 65 mph

The end of test is determined when the bus cannot maintain 65 mph or when the SOC reaches a minimum recommended by the bus manufacturer. The DC energy consumed by the bus for each of the ten test sections above is recorded. The battery system is recharged to full SOC at the end of the test, following procedures specified in SAE J 1634-2017. During the recharge, the DC energy (into the battery system) and the AC energy (into the charger) are recorded.

6-III. TEST ARTICLE

The test article is 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.

The following equipment is used for measuring AC energy and DC energy:

1. Fluke 1730 Energy Logger (3-phase/single phase AC energy)
2. Fluke 345 Power Quality Clamp meter (DC energy)

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 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.

The data as noted in 6-II are recorded and calculations are performed according to SAE J 1634-2017.The results: DC energy (Wh), AC energy (Wh), and the range of the bus (miles) for all three drive cycle are reported in the energy economy data form.

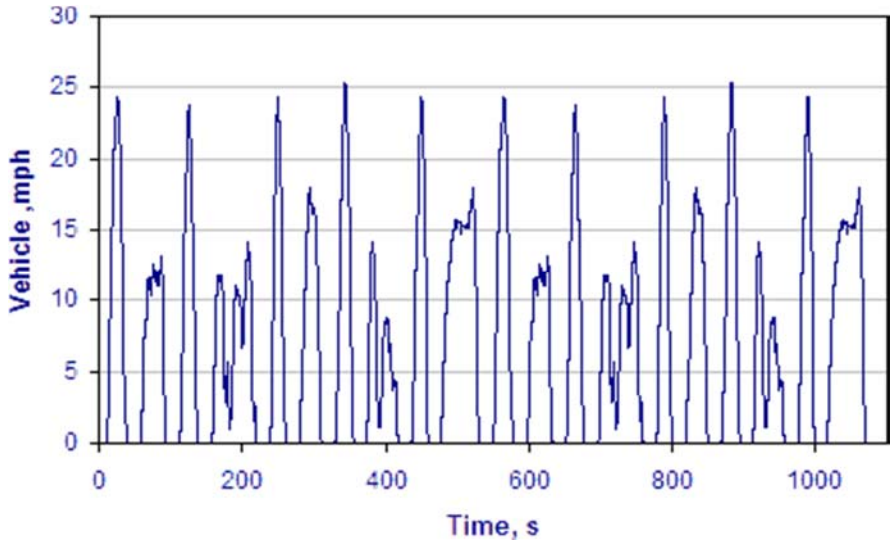

Figure 1. Manhattan Driving Cycle (duration 1089 sec, Maximum speed 25.4 mph, average speed 6.8 mph)

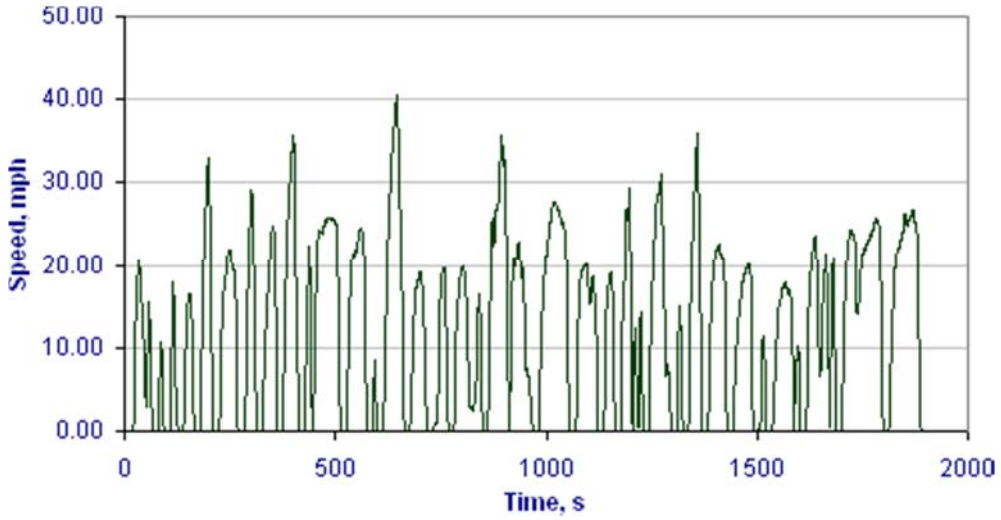

Figure 2. Orange County Bus Cycle (Duration 1909 Sec, Maximum Speed 41 mph, Average Speed 12 mph).

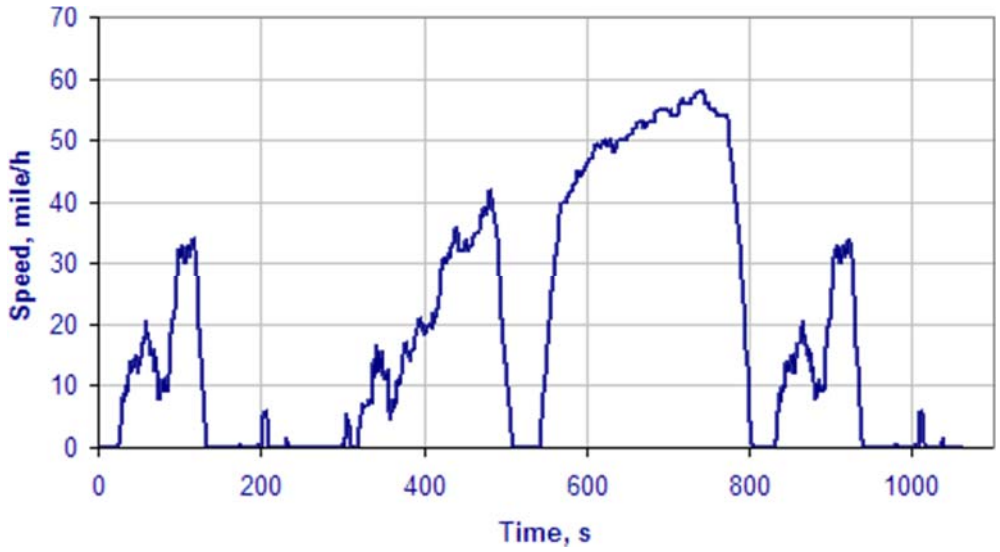

Figure 3. HD-UDDS Cycle (duration 1060 seconds, Maximum Speed 58 mph, Average Speed 18.86 mph).