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

Pass/Fail

OCTOBER 2017
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 (CAFÉ) 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 testing. 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 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 test cycles 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. Energy consumption for each test cycle is calculated as recommended in the standard.

The single Cycle Test (SCT) procedure also generally conforms to SAE J 1634-2017. The test is started with a fully charged battery system, and the same test cycle, namely Manhattan Cycle, or the Orange County Bus Cycle, or the HD-UDDS is repeated until end of test, determined as above. The
DC energy and the AC energy consumed during the test is recorded. Energy consumption for each test cycle is calculated as recommended in the standard.

6-III. TEST ARTICLE

The test article is a heavy-duty transit bus with a specified service life.

6-IV. TEST EQUIPMENT/FACILITIES/PERSOONNEL

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 conducting the test.

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.

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).
All revisions to this test must be identified on this page. Briefly describe each revision in the space provided below.

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