SAE International®

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1321 FEB2012

Issued 1981-10
Revised 2012-02

Superseding J1321 OCT1986

Fuel Consumption Test Procedure - Type II

RATIONALE

The previous J1321 document lacked statistical analysis of test data and lacked constraints on test criteria required to resolve current and anticipated fuel consumption measurement increments. Additionally, results from previous versions of this procedure have been reported without precision tolerances. To address the current limitations of the procedure it was determined that a full revision of the document was required.

FOREWARD

The increased demand for greater fuel efficiency, improved freight efficiency and reduced emissions coupled with major advancements in powertrain systems, low rolling resistance tires, aerodynamics, and system integration have led to a growing need for an accurate procedure for determining the impact of various technologies on fuel consumption. To address these needs the SAE Truck and Bus Aerodynamics and Fuel Economy Committee sponsored the SAE Truck and Bus J1321 Revision Task Force to revise this recommended practice. The task force was comprised of truck manufacturers, test facility experts, engine manufacturers, technology developers and technical experts from academia. This recommended practice draws from a large body of test data, input from major testing laboratories and industry groups.

This recommended practice describes fuel consumption test procedures for on-track and on-road testing. The test procedure utilizes rigorous engineering procedures and accepted statistical analysis methods to determine the fuel consumption for trucks and buses. Test results that do not rigorously follow the method described are not intended for public use and dissemination and shall not be represented as a J1321-Type II test result.

This document:

(1) Describes test procedures that determine and document the percent change in fuel use due to a change in vehicle/powertrain configuration, set-up, or operation for a measured set of environmental conditions present during the test.

(2) Identifies parameters that improve the precision of the measured fuel use data relative to environmental test conditions.

(3) Ensures uniformity and transparency of test results by defining the format and content required for reporting and the public use of all test results.

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1. SCOPE

This document describes a rigorous-engineering fuel-consumption test procedure that utilizes industry accepted data collection and statistical analysis methods to determine the change in fuel consumption for trucks and buses with GVWR of more than 10,000 pounds. The test procedure may be conducted on a test track or on a public road under controlled conditions and supported by extensive data collection and data analysis constraints. The on-road test procedure is offered as a lower cost alternative to on-track testing but the user is cautioned that on-road test may result in lower resolution (or precision) data due to a lack of control over the test environment. Test results that do not rigorously follow the method described herein are not intended for public use and dissemination and shall not be represented as a J1321-Type II test result.

1.1 Purpose

This recommended practice provides a standardized test procedure to determine the change in a vehicle's fuel consumption by adding, removing, or modifying a vehicle component or system. The procedure utilizes two or more identical medium to heavy-duty single unit or combination vehicles weighing more than 10,000 pounds. Vehicles used in the test include an unchanging control vehicle, to provide reference fuel consumption, and test vehicle(s) that are modified during the test process. All vehicles are operated simultaneously and over the identical test circuit during each test run. The test procedure provides a percent difference in fuel consumption between two conditions of a test vehicle(s). A discussion of the data collection and statistical analysis approach are presented in Section 6 and Appendix B.

1.2 Limitations and Requirements

The fuel consumed by a moving vehicle is dictated by the aerodynamic and rolling resistive forces acting on the vehicle, with aerodynamic resistance being the dominant force for most vehicles covered by this procedure. In conducting a fuel consumption test, regardless of the technology or system under investigation, it is critically important that unknown and/or uncontrolled variations in aerodynamic and rolling forces are minimized throughout the test process.

a. Minimizing the variation in rolling resistance between vehicles used during a test is accomplished in this procedure by ensuring all vehicles operate at speeds and with tire setup, weight characteristics, and on road surfaces that are within the allowable variations in test criteria described within this document.

b. The minimization of aerodynamic variation is accomplished in this procedure by using vehicles with identical external shapes that are operated at identical speeds and by ensuring that vehicle interference effects, air temperature and wind conditions are within the allowable variations described within this document. Because fuel consumption and data quality is highly sensitive to the presence of wind it is suggested that testing should be performed in as low a wind speed as possible. The maximum mean wind speed for a run shall be limited to less than or equal to 12mph (19.3 km/h). A detailed discussion of wind effects can be found in Appendix A.

The limitations of this procedure are defined below. It is important that all test limitations described below in items “a” through “o” be reviewed and rigorously followed. These limitations are applicable to on-track and on-road testing.

a. Only fuel consumption data obtained from this procedure may be represented as a J1321-Type II test result.

b. Test results generated from any test that does not rigorously follow this method and the test reporting requirements are not intended for public use and dissemination and shall not be represented as a J1321-Type II test result.

c. A Test is comprised of a Baseline Segment and a Test Segment. Each Baseline Segment and each Test Segment are comprised of a minimum of three (3) Runs of the Control Vehicle and Test Vehicle(s). A single Run is a complete circuit of the test route by both the Control Vehicle and Test Vehicle(s) where both the Control Vehicle and Test Vehicle(s) are operated simultaneously.

d. All test results must be presented; in the defined format, with the defined statistical analysis, with vehicle configuration description and with environmental test information described in this procedure.

e. Test results are valid only for the vehicle configuration, test conditions and test cycle under which the test was conducted.

f. All vehicles used in the test must have the same; external surface contours (preferably the same make, model and year), tires and wheels (preferably the same type, condition and mileage) aerodynamic configuration, power-train, and are in the same operational and physical condition. Tread must be of the same scalable depth.

g. All vehicles must be operated at identical speed, on identical road surfaces and within allowable temperature and wind conditions described within this document. See items h and i below.

h. The allowable mean wind speed during a run shall be limited to values less than or equal to 12mph (19.3 km/h). Maximum wind gust (less than 2 sec duration) during a run must be less than 15 mph (24.15 km/h). The recommended maximum allowable change in mean wind speed between segments and between runs of a segment shall be less than or equal to 5 mph (8.05 km/h).

i. Tests shall only occur when the ambient air temperature during a run is between 40 °F (4.44 °C) and 100 °F (37.8 °C).The recommended maximum allowable change in air temperature between segments and between runs of a segment shall be ≤30 °F (16.7 °C).

j. All Runs are valid and all test data collected from each Run are valid. All test data must be included in the statistical analysis process. Test data may be excluded from the statistical analysis if a documented equipment failure or malfunction or driver error has occurred or weather condition requirements have been violated. The source of the failure must be recorded and documented in the test report.

k. The test site environmental conditions must be recorded through out the test. The required environmental data include, but not limited to: temperature, wind speed and direction. The data sampling rate must be sufficient to capture any transient environmental effects.

l. The test procedure does not generate aerodynamic data.

m. The general applicability of a valid test result to different environmental factors may be determined when a subsequent valid test result produces a statistically similar value to the initial valid test result.

n. If the confidence interval value for a test is greater than or equal to the nominal test value, as determined by the statistical analysis results, it is recommended that additional runs may be conducted to reduce the confidence interval value to less than the nominal test value. For example, if the test result is a nominal value of 3% ± a confidence interval value of 4%, additional runs may reduce the confidence interval to a value less than the nominal value. If additional runs do not show statistically conclusive results, the user must conclude that the change in fuel consumption is either being influenced by variations in the test environment (i.e. weather, driver, etc.) or is less than the test precision.

o. This test procedure requires the use of identical vehicles and therefore it cannot be used to determine the difference in fuel consumption between two different test vehicles (i.e. truck to truck comparisons). It is recommended that SAE J1526 test procedure be used to determine the difference in fuel consumption between two different test vehicles.

1.3 Document Use

All users of this document are encouraged to review all sections of this document prior to executing a test program.

This document is structured to service both the novice and the expert user.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the current revision of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1252 SAE Wind Tunnel Test Procedure for Trucks and Buses

SAE J2084 Aerodynamic Testing of Road Vehicles – Testing Methods and Procedures

SAE J1526 Joint TMC/SAE Fuel Consumption In-Service Test Procedure Type III

SAE Paper No. 810025 “Transit Bus Fuel Economy Test”, H. H. Buckel

SAE J1594 Vehicle Aerodynamics Terminology

SAE 2009-01-1605 "Fuel Consumption Tests for Evaluating the Accuracy and Precision of Truck Engine Electronic Control Modules to Capture Fuel Data", M. Surcel J. Michaelsen

2.1.2 Other Publications

Aerodynamics of Road Vehicles, edited by W.H. Hucho, SAE 1998

Experimental Validation and Uncertainty Analysis for Engineers, Coleman, H. and Steele, G., 3rd ed., Wiley, 2009

Wind Energy Resource Atlas of America, DOE/CH 10093-4, Oct. 1986, DE86004442

2.2 Related Publication

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2711 Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles

SAE J2881 Measurement of Aerodynamic Performance for Mass-Produced Cars and Light-Duty Trucks

SAE J1263 Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques

SAE J2263 Road Load Measurement Using Onboard Anemometry and Coastdown Techniques

SAE J1264 Joint RCCC/SAE Fuel Consumption Test Procedure (Short Term In-Service Vehicle) Type 1

2.2.2 Other Publications

TMC Report, "Report of Frederick, Maryland, Truck and Bus Fuel Economy Demonstration, Conducted October 22-November 1, 1979, by the Joint TMC/SAE Task Force for In-Service Test Procedures of The American Trucking Industry," November 1980.

TMC RP 1109, Type IV Fuel Economy Test Procedure

TMC RP 1102, TMC/SAE In-Service Fuel Consumption Test Procedure - Type II

TMC RP 1103, TMC/SAE Fuel Consumption In-Service Test Procedure Recommended Practice - Type III

3. DEFINITIONS

3.1 ACCURACY

The extent to which a given measurement agrees with the standard value for that measurement. Accuracy cannot be determined for this test procedure because of the lack of a standard value.

3.2 AERODYNAMIC DEVICE

A structure or system added to the exterior of the vehicle for altering the aerodynamic forces acting on the vehicle

3.3 BASELINE SEGMENT (BS)

A minimum of three (3) Runs with both the Control Vehicle and the unmodified Test Vehicle running simultaneously.

3.4 CARGO WEIGHT (CW)

Is equal to the Gross Vehicle Weight minus the Tare Weight

3.5 CLASS 3 TRUCK/COMBINATION VEHICLE

Vehicle with gross vehicle weight (GVWR) of 10,001-14,000 lbs (4,536.5 – 6,350.4 kg)

3.6 CLASS 4 TRUCK/COMBINATION VEHICLE

Vehicle with gross vehicle weight (GVWR) of 14,001-16,000 lbs (6,350.09 – 7,257.6 kg)

3.7 CLASS 5 TRUCK/COMBINATION VEHICLE

Vehicle with gross vehicle weight (GVWR) of 16,001-19,500 lbs (7,258.1 – 8,845.2 kg)

3.8 CLASS 6 TRUCK/COMBINATION VEHICLE

Vehicle with gross vehicle weight (GVWR) of 19,501-26,000 lbs (8,845.7 – 11,793.6 kg)

3.9 CLASS 7 TRUCK/COMBINATION VEHICLE

Vehicle with gross vehicle weight (GVWR) of 26,001-33,000 lbs (11,794.1 – 14,968.8 kg)

3.10 CLASS 8 TRUCK/COMBINATION VEHICLE

Vehicle with gross vehicle weight (GVWR) of 33,001 or more lbs (14,969.3 kg)

3.11 COMPONENT

Within the limitations of this test procedure, a component is defined as a part that can be added, attached or removed from the powered vehicle and/or a pulled vehicle. This may include but not be limited to fluids, lubricants, fuel additives, tires, aerodynamic enhancements, exhaust after-treatment, engine, or other power-train devices. Components which are not considered testable are such systems that:

- integral part of the overall system (i.e. Hybrid systems due to rotational inertial of motor system), unless the entire system and subcomponents are changed

- complete powered vehicle or powered portion of a combination vehicle

3.12 CONTROL VEHICLE (CV)

The Control Vehicle is used to obtain reference data for the Test and is not modified in any way or used for any other purpose during the entire Test.

3.13 COMBINATION VEHICLE

An equipment configuration that includes a separate power unit and at least one unpowered pulled vehicle (trailer).

3.14 DATA POINT (DP)

The quantity of fuel consumed by a single vehicle during a Run.

3.15 DRIVER

Operator of a vehicle

3.16 DUTY/ DRIVING CYCLE

The cycle is comprised of; length in miles, number of complete stops, distance between stops, average road speed using only rolling time, number of idle periods, length of total idle time and length of idle periods, engine speed and accessories used during idle period, reverse driving, and any unique shifting transmission or operational activity.

3.17 FIFTH WHEEL

A pivoting coupling device attached to a leading vehicle or component of a combination vehicle that supports the front of a trailer

3.18 FLOW METER

An instrument used to measure the rate of flow-or volume of a fluid.

3.19 FUEL VOLUME MEASURING DEVICE/PROCESS

The fuel volume measuring device/process with proven capability of measuring fuel volume within 0.5% for fuel consumption volumes typical of Run must be used.

3.20 FUEL WEIGH TANK

An easily removable fuel tank. The tank should be appropriately sized to complete a test run without risk of inducing air into the fuel lines. A good rule of thumb is approximately 2 times the estimated fuel necessary to complete a Run. The tank should be fitted with quick disconnect fuel lines so that it can be removed from the vehicle for weighing. The supply and return lines should be adequately spaced to ensure air does not enter the lines. The tank should satisfy Department of Transportation (DOT) safety requirements, see 49 CFR part 393, subpart E.

3.21 GAP, AERODYNAMIC

Longitudinal distance between the aft most point of the cab external surface, including aerodynamic side fairings, and the forward most point of the cargo carrying portion of the vehicle.

3.22 GAP, TRACTOR TO TRAILER

Longitudinal distance between the vertical flat surface of the back of the cab / sleeper to the vertical flat surface on the front of the trailer.

3.23 GLOBAL POSITIONING SYSTEM (GPS)

A system of satellites, computers, and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.

3.24 GRAVIMETRIC

Measurement by weight.

3.25 GROSS COMBINATION WEIGHT (GCW)

Applies to combination vehicles. The combination of the total weight of the tractor (powered unit) the total weight of the trailer and the weight of the freight load.

3.26 GROSS VEHICLE WEIGHT (GVW)

Applies to single unit vehicles. The total weight of a vehicle with maximum freight load.

3.27 GROSS VEHICLE WEIGHT RATING (GVWR)

The maximum allowable total mass of a road vehicle when loaded including the weight of the vehicles, fuel, passengers, cargo and trailer tongue weight.

3.28 MEAN

The sum of the values of a random variable divided by the number of values

3.29 NIST

National Institute of Standards and Technology

3.30 OBSERVER

A passenger in the vehicle responsible for maintaining and recording various Test operational conditions and assisting the driver.

3.31 OEM

Original Equipment Manufacturer.

3.32 POWERED UNIT

The portion of the vehicle which includes the primary propulsion system.

3.33 PRECISION

The extent to which a given set of measurements of the same sample agree with their mean.

3.34 SCALE

The scale is used to weigh the fuel weight tank and its contents during the test process. The scale must have sufficient capacity and resolution to support the testing process as described in section 5.0.

3.35 SEMITRAILER

Truck trailer supported at the rear by its own wheels and at the front by a fifth wheel mounted to a tractor or dolly.

3.36 SINGLE UNIT VEHICLE

A vehicle which has the powered portion and freight carrying unit mounted to the same chassis.

3.37 STANDARD DEVIATION

A measure of the spread or scatter of measures around the mean of those measures.

3.38 TARE WEIGHT (TW)

Weight of empty vehicle with full fuel tanks, lubricants and trailer but without occupants or load.

3.39 TEST (T)

A test is composed of a Baseline Segment and a Test Segment

3.40 TEST ROUTE, ON-ROAD

The route shall be representative of the desired drive cycle under investigation. The route should have minimal traffic to increase repeatability. For consideration, roadways using a cloverleaf at the turn around point will allow consistent and repeatable operation of both vehicles for every run. The route shall have a common start and end point.

3.41 TEST ROUTE, ON-TRACK

For on-track tests a test route consist of a specified number of laps around the test track.

3.42 RUN (R)

A complete and simultaneous circuit of the specified Test Route by both the Test Vehicle(s) and the Control Vehicle. The Run must be completed without the occurrence of an equipment failure or malfunction, driver error, or a failure to obtain all required weather and operational data. Each Run generates one Data Point for the Test Vehicle and one Data Point for the Control Vehicle.

3.43 TEST SEGMENT (TS)

A minimum of three (3) Runs with both the Control Vehicle and a modified Test Vehicle.

3.44 TEST TRACK

A closed circuit road used to evaluate vehicle performance.

3.45 TEST VEHICLE (TV)

The Test Vehicle is used to evaluate modifications to a vehicle between the Baseline Segment and Test Segment of a Test. The modifications to the Test Vehicle may be components, technologies, or system changes.

3.46 TMC

Technology and Maintenance Council

3.47 TRACTOR

A vehicle designed primarily to pull a semi-trailer by the use of the fifth wheel which is mounted over its drive axlel(s). May be called a truck/highway tractor to differentiate it from a farm tractor.

3.48 TRAILER

A freight carrying unpowered unit pulled by a powered unit

3.49 TRUCK

A vehicle which carries cargo in a body (van, tank, etc.) which is mounted to a chassis, possibly in addition to a trailer which is towed by the vehicle.

3.50 TRUCK-TRAILER

A truck-trailer combination consists of a truck that holds cargo in its body which is connected to its chassis, and which tows a trailer.

3.51 UNCERTAINTY

Having limited knowledge where it is impossible to exactly determine the true value, thus having more than one possible outcome

3.52 VEHICLE RELATIVE VELOCITY (V)

"V" is the sum of the "Vehicle Velocity "and the component of "Wind Velocity" along the longitudinal axis of the vehicle.

3.53 VEHICLE VELOCITY (V_T)

Velocity of the vehicle relative to the roadway.

3.54 WIND ANGLE (Φ)

Angle of the mean wind direction relative to the vertical centerplane of the vehicle

3.55 WIND VELOCITY (V_W)

The rate of motion of the air past a fixed point

3.56 WIND GUST

A sudden acceleration of the wind velocity with a duration less than 2 sec.

3.57 YAW ANGLE (Ψ)

Is the effective wind angle experienced by the vehicle based upon vehicle ground velocity, wind velocity and wind angle, relative to the vehicle heading. Vehicle drag increases exponentially with increasing yaw angle.

4. TEST PLANNING

The following two sub sections provide an overview of relevant test criteria. This information is provided for those with minimal experience in performing this class of fuel consumption testing.

4.1 Data Quality Considerations

A detailed discussion of the statistical analysis approach is contained in Appendix B. A sample data analysis is shown in Appendix C.

In general an on-track test provides improved data quality compared to an on-road test. The test track offers reduced aerodynamic interference from vehicles and road structures, uniform test surface, ability to collect high quality environmental data, along with improved vehicle speed control while minimizing driver workload.

It is recognized that a user may need to balance data quality with test cost when evaluating fuel consumption improvement technologies. A summary of criteria that are the same for both on-track and the on-road test methods are listed below in table 1. Table 2 shows criteria that differ for on-track and on-road testing. Only test results that satisfy the criteria described within this document may be labeled as J1321-Type II test results. On-track testing shall only use on-track criteria. On-road testing may use either on-track or on-road criteria.

TABLE 1 - CRITERIA THAT ARE THE SAME FOR ON-TRACK AND ON-ROAD TESTING

Criteria	**Recommended On-Road and On-Track Requirement**
Vehicles:	Identical Test and Control Vehicle
Vehicles Setup:	Identical
Vehicles Load:	Identical
Vehicles Condition:	Identical
Mean. Wind Speed during a Run:	≤12 mph (19.32km/h) (see section 6.1.3.2)
Mean Wind Speed Change between Segments and Runs	≤5 mph (see section 6.1.3.2)
Allowable Temperature Range:	40 to 100°F (4.44 to 37.8°C) (see section 6.1.3.2)
Temperature Change during Test:	≤30°F (-1.1°C) (EX: 50 to 80°F (10 to 26.7°C) within a Test) (see section 6.1.3.2)
Rain:	None allowed
Weather Measurements Samples:	Minimum of 1 sample/60 sec. During sample period.
Maximum Time Between Runs:	NA – Constrained by Weather Conditions
Speed Control:	GPS matched with use of cruise control
Spacing Control:	GPS matched with use of cruise control
Minimum Vehicle Spacing:	1500 ft.
Fuel Measurement Method:	Gravimetric

TABLE 2 - CRITERIA THAT ARE DIFFERENT FOR ON-TRACK AND ON-ROAD TESTING

Criteria	**On-Track Requirement**	**On-Road Requirement**
Test Site	Track	Road
Instantaneous Vehicle to Vehicle Speed Variation	• ± 1 mph (1.61km/h) for constant speed test on level surface or track • Duty cycle and/or grade dependent	Duty cycle and/or grade dependent
Grade Change	< 3.5%	Duty cycle dependent
Run length	> 50 miles (80.5km)	> 100 miles (161km)
Weather Measurements Sites	Minimum of 1 location	Minimum of 3 locations (see section 6.1.3.2)

4.2 Test Considerations

The user of this document should review and consider the factors listed below when planning a fuel consumption test. Additional information on each item can be found in Sections 5.0 and 6.0 and Appendices A, B, C and D.

4.2.1 Test Objective

This recommended practice will quantify the impact on a vehicle's fuel consumption resulting from adding, removing, or modifying a component or system or a change in vehicle operation. Representative components or systems that may be examined are those that change aerodynamic resistance, rolling resistance, power train efficiency, lubricant effectiveness, fuel, and auxiliary load for a given duty cycle.

4.2.2 Vehicle Type and Configuration

Identical vehicles shall be used. Identical vehicles are defined as having the same; external surface contours (preferably the same make, model and year), tires and wheels (preferably the same type, condition, mileage and same tire model per tire position) aerodynamic configuration, power-train, and are in the same operational and physical condition. It is acceptable to utilize vehicles of a different model year if no features of the aerodynamic, mechanical or system components have changed. It is understood that vehicle and certified engine model year in these weight classes may not be aligned by calendar or model year of build. Tires should have a minimum of 500 miles (805 km) of use. The vehicles should have at least 500 miles (805 km) on the odometer if tested new by an OEM or at least 10,000 (16,100 km) miles if tested by any other person or organization and all vehicles tested should conform to the following rules.

a) The mileage on all vehicles (Control and Test) should be within 1,000 miles (1,610 km) of each other if the odometer on one vehicle is less than 5,000 miles (8,050 km).

b) The mileage on all vehicles should be within 3,000 miles (4,830 km) of each other if the odometer on all vehicles is greater than 5,000 miles (8,050 km) but less than 10,000 miles 16,100 km) on one vehicle.

c) The mileage on all vehicles should be within 10,000 miles (16,100 km) of each other if the odometer on all vehicles is greater than 10,000 miles (16,100 km) but less than 30,000 miles (48,300 km) on one vehicle.

d) No limit if the odometer on all vehicles is greater than 30,000 miles (48,300 km).

4.2.3 DPF/SCR Preconditioning

Vehicles equipped with advanced after treatment, including diesel particulate filters (DPF) lean NOx traps or catalysts (LNT, LNC) or selective catalytic reduction (SCR) systems may require after treatment preconditioning before conducting each test sequence. The objective of the process will be to minimize Test to Control Vehicle variability due to unforeseen regeneration events and associated increase in fuel consumption. The preconditioning may consist of a stationary forced DPF regeneration using a service tool or other passive regeneration methods recommended by the engine or after treatment manufacturer. It is recommended that the regeneration be completed several hours prior to the preconditioning warm-up period such that thermal stabilization of the test vehicles is achieved before conducting test runs. (note: If a DPF regeneration occurs during a run the run will be invalid and shall be removed from the test data set. If the user lacks the capability to monitor appropriate regeneration messages over the controlled area network (CAN) data bus, the exhaust temperature across the DPF should be measured to determine occurrence of a DPF regeneration as indicated by a temperature increase across the DPF. Regeneration may be indicated by an increase in fuel consumption although may not be obvious from the T/C ratio of the effected run.)

4.2.4 Test Speed

The test speed should be representative of in-service operation and be within the capability of the test vehicles and road conditions. Vehicles are to be operated according to vehicle, engine, and transmission manufacturers' recommendations (engine speeds and shift points). If the test vehicles can be operated in more than one transmission or differential ratio over any part of the test route at the speed selected, a pre-determined driving procedure must be specified and used for all vehicles.

4.2.5 Test Track

Track selection should consider track shape, length, road surface, grade change, speed limitations, and historical weather patterns. The track should be a continuous closed circuit that allows for the safe operation of the test vehicle at the test speed(s) over the complete track circuit without interruption. The track road surface should be representative of highway surfaces. It is recommended that the test track circuit shall have a grade change < 3.5%.

4.2.6 Weather

A primary source of error during a truck or bus fuel consumption test is variations in weather conditions. See sections 5.0, 6.1.3.2 and appendix A for additional information, cautions and limitations.

4.2.7 On-Road Test Route

For on-road tests, a test route must have a start and stop point at the same approximate geographical location. The route should have minimal traffic to increase repeatability. For consideration, roadways using a cloverleaf at the turn around point will allow consistent and repeatable operation of both vehicles for every run.

4.2.8 Trailers

If trailers are used, the trailers must be permanently assigned to a specific tractor throughout the entire test. Trailers must not be exchanged between the vehicles. A trailer may be a changeable component for the test vehicle only. The trailer for the control vehicle must not change under any test scenarios.

4.2.9 Vehicle Weight and Distribution

If vehicle weight and/or weight distribution are not a test variable the vehicle weight and weight distribution for the test should be representative of the fleet operations and be within the capability of the vehicles under test. Weight distribution should be configured to equally load each axle in order to reduce the bias from trailer and tractor axles. All vehicles must have the same total weight and weight distribution. The cargo weights selected for the test should be representative of the fleet operations and within the capability of the vehicles under test. Static weights should be selected in preference to live or liquid loads that may shift during the course of normal testing. Cargo weight must not change during a test unless a change in weight is a factor being tested. If the total weight between the Control and Test vehicles cannot be matched the difference must be ≤1.5%. If the weight distribution cannot be matched between the Control and Test vehicles the difference in each axle load must be ≤5% or ≤ 500 lbs (226.8 kg) which ever is lesser.

4.2.10 Fuel Use Measurement

Gravimetric fuel measurement is preferred for this test procedure. See section 5.0 and 6.0 for additional details. All portable tanks used in a test must be weighed on the same portable scale. A flow meter may be used if the accuracy requirements described in section 5.0 and 6.0 are satisfied.

4.2.11 Drivers

Drivers should be sufficiently skilled so that test results are not affected by the driver's technique during the test period. Drivers should also have a strong motivation for unbiased results and excellence of test procedure conduct.

4.2.12 Observers

Observers may be assigned (but are not required) to each vehicle to record data and assist with complex driving cycles.

4.2.13 Vehicle Condition

To minimize test variability, the condition of all vehicles used in the test procedure must be identical and in similar condition.

4.2.14 Aerodynamic Devices

Aerodynamic drag reduction equipment (fairings and air flow control devices) should be tested in very low wind conditions for smallest possible result tolerance. See Appendix A for more information on this topic.

4.2.15 Odometer Precision

If odometers and speedometers are used the precision of all vehicles should be determined using GPS during the warm-up test or during the vehicle setup process and compensations made for error during actual tests runs.

5. INSTRUMENTATION AND EQUIPMENT

Care must be taken in the collection of all test data. This section provides specific information regarding instrumentation and measurement equipment required for a successful test. To minimize variation in fuel consumption data quality the environmental effects and vehicle operational characteristics must be monitored continually throughout the test program. All instrumentation used in the test process should be NIST traceable and all fuel consumed shall meet all applicable ASTM International standards for fuel for the intended application.

5.1 Fuel Consumption

Only the two methods described in this section may be used to measure the fuel consumed during a test. These methods fall into two categories; gravimetric and volumetric. To minimize errors in the test process the gravimetric method is preferred for both on-track and on-road tests. A discussion of this fuel measurement approach is provided in section 5.1.1 below.

A flow meter may be used if the flow meter can satisfy the accuracy requirements described in section 5.1.2 and 6.0.

The following fuel use measurement methods are not approved and shall not be used

a. Data obtained from the electronic control module (ECM).

b. Volumetric measurements obtained by measuring fuel volume in the fuel tank.

c. Volumetric measurements obtained from a fuel dispensing system.

5.1.1 Gravimetric

The gravimetric method is a direct measurement of the weight of the fuel consumed. Gravimetric fuel measurement instrumentation and equipment consist of the following items.

a. Fuel Tank: An easily removable fuel tank appropriately sized to complete a test Run without risk of inducing air into the fuel lines - a good rule of thumb is approximately 2 times the estimated fuel necessary to complete a Run. The tank should be fitted with quick disconnect fuel lines so that it can be removed from the vehicle for weighing. The supply and return lines should be adequately spaced to ensure air does not enter the lines. For on-road testing the user shall verify that the removable fuel tank satisfies DOT safety requirements.

b. Fuel Cooler: A fuel cooler/radiator capable of maintaining the temperature of the fuel in the tank below the engine OEM's maximum allowed temperature (normally 160°F (71.1 °C)) may be required. The cooler should be located in a manner to obtain the necessary air flow while not greatly affecting the aerodynamics of the vehicle. Pressure drop across the fuel cooler should not impede flow to a point where manufacturer specified delivery pressure and volume is not maintained.

c. Scale: A calibrated digital scale having sufficient capacity and capability to accurately weigh portable fuel tanks throughout the full range of tested fuel levels. The scale should have a display resolution of no more than 0.1% of the minimum fuel consumption value for a test run. The scale shall be verified by calibration to be accurate within ± 0.25% of the measurement range observed throughout the test. A calibration weight within this test range shall be used to verify the scale repeatability prior to each sequence of measurements. Weight measurements should be recorded immediately after the display has settled to a final value. Portable fuel tanks shall be placed on the scale platform in the same location and orientation.

5.1.2 Volumetric, Flow Meter

A calibrated flow meter may be used if it has sufficient capacity and capability to accurately measure fuel flow or volume throughout the full range of engine loads. The fuel flow meter shall be verified by calibration to be accurate within ± 0.5% throughout the measurement range of test samples and fuel temperatures

5.2 Weather

The test procedure requires that wind speed, wind direction, air temperature, humidity, and barometric pressure be measured throughout the test. A number of commercially available instrumentation systems are available for measuring the weather parameters listed above. The wind measurement device must have a wind speed accuracy of ± 0.5 mph (.81 km/h)and a wind direction accuracy of ±2°. The other weather condition measurement sensors or instruments must have a resolution value less than 0.5% of the maximum value measured during the test.

5.3 GPS Vehicle Operation

To ensure acceptable data quality, the test procedure require each Run be executed in a repeatable manner. This can only be accomplished by a close monitoring of vehicle speed throughout the Run. It is recommended that a GPS unit (or devices and systems of equal accuracy and precision) capable of measuring and logging road speed within 0.1 mph be used. To further improve data quality the trip average feature of the GPS system may also be used as an indicator for acceleration rate repeatability from run to run as well as an indicator for final cruise speed between the control and test vehicles.

6. TEST PROCEDURE

Results obtained from a Test that does not rigorously follow these procedures shall not be represented as a J1321-Type II test result.

It is recommended that this procedure be performed on a test track to ensure greater control over the test environment resulting in improved data quality. The on-track test procedure is described in section 6.1.

The on-track test procedure has been structured to provide high quality test data. The procedure is detailed in three sections; test preparation (6.1), test process (6.2), and data analysis and reporting (6.3). Supporting information can be found in the preceding sections 2.0, 3.0, 4.0 and 5.0 above and in Appendices A, C and D.

To reduce cost and to support the needs of all sectors of the truck and bus community several modifications to the on-track procedure are allowed for on–road testing. These modifications are defined and embedded within subsections 6.1.1 and 6.2 and noted by enclosed [brackets].

6.1 Test Preparation

This section contains all necessary information and instructions to prepare the test facility, test vehicles, instrumentation, and personnel for a successful test.

To assist the user a number of forms are provided in appendix D. The user of this procedure is not required to use the supplied forms but is required to document the specific information and collect the data described in the forms provided. The user shall use the data analysis procedure described in this document and the supplied data analysis software.

6.1.1 Test Track

The test track should be inspected prior to testing. The test track should be a continuous closed circuit that allows for the safe operation of all test vehicles at the selected test speed over the complete track circuit without interruption to the target drive cycle. The track road surface should be similar to that found on a US highway. The test track circuit shall have a grade <3.5%.

[On-Road Testing ONLY: The on-road test route should be inspected prior to testing. The test route circuit should allow for the safe operation of all test vehicles at the selected test speed(s) over the circuit without interruption to the target drive cycle. The road surface should be similar to that found on a U.S. highway. The test circuit shall have a grade < 5%.]

6.1.2 Vehicle and Equipment

All test vehicles and equipment shall be documented. A description of the documentation requirements and the information and data collection requirements are contained on Form D1, see appendix D.

In general, all test vehicles shall:

a. be identical (preferably of the same make, model and year) and of the same condition with equivalent number of miles on the vehicle and tire wear. See section 4.2.2 for detailed description.

b. be the same weight and have the same weight distribution within 0.5% or < 500 lbs (226.8 kg) over each axle

c. be in proper operating condition.

d. have fully functional engine and after treatment systems without diagnostic trouble codes or other engine/emission service indicators illuminated (malfunction indicator lamp (MIL), diesel exhaust fluid (DEF)).

Specifically, all test vehicles shall be in identical mechanical conditions, be representative of the operator's vehicle(s) involved in the test, and (except in the case where the vehicle feature is the item being evaluated) have the following as noted below and listed on Form D4, see appendix D.

a. Each engine speed control set to manufacturer's recommendation or the operator's standard.

b. New air cleaner element and new fuel filters are recommended.

c. Each vehicle shall be clean and free of damage or missing body parts.

d. It is preferred that cab windows for all vehicles are closed. If windows are open the openings shall be the same in each vehicle for the entire test. For transit buses, all windows should stay the same (open or closed) for entire test.

e. Accessory load for each vehicle as consistent as possible (for example, by turning air conditioning off, defroster off, blower speed at the same setting, and lights on).

f. Trailer free of damage to exterior surfaces.

g. Truck/tractor alignment checked and proper. Trailer axle alignment checked and proper.

h. Each vehicle properly lubricated prior to test. All fluid levels should be checked and be at prescribed levels.

i. Temperature controlled fan drives shall be set to the same operating mode throughout the test.

j. Cold tire pressures measured and inflated to vehicle or tire manufacturer standard within a tolerance of ±1 psi (6895 Pa). Tire pressures need to be set at the beginning of the day following overnight cold soaks. Ensure solar loading on all tires is consistent prior to adjusting pressures.

k. A stall check made on vehicles equipped with automatic transmissions and torque converters.

l. Exhaust system free of mechanical and operational defects.

m. Proper brake adjustment.

n. All emission after treatment components must be in proper working condition. Vehicles that rely on a reductant chemical to control criteria pollutants must have sufficient volume on board to complete all testing.

Prior to the initial Run all vehicles must be checked for mechanical malfunction that would affect test results. Typical checks would include:

a. Oil pressure and leaks.

b. Brake air system leaks

c. Coolant temperature and leaks.

d. Exhaust gas temperature.

e. Engine air filter restriction.

f. Electrical load.

g. Tire pressures.

h. Brake dragging (i.e. temperature).

i. Exhaust smoke.

j. Observed ability to maintain selected test speed.

k. Transmission or differential leaks.

l. Intake manifold pressure (turbocharger boost) and other intake system losses

m. After treatment condition, state of DPF loading and regeneration state. Drivers should note dash displays that indicate or broadcast regeneration state or a DPF illuminated before keying off after warm up.

n. Check/investigate all vehicle diagnostic caution and warning signals/alarms and resolve all vehicle operational concerns prior to proceeding with the test

It is recommended that the above list of checks should be executed between runs.

6.1.3 Instrumentation

All instrumentation type, specification and placement shall be documented. A description of the documentation requirements and the information and data collection requirements are contained on Form D2, see appendix D. See sections 4.0 and 5.0 for additional information.

All required instrumentation to obtain weather, fuel consumption and vehicle operating conditions for the preferred procedure shall be evaluated for proper operating performance prior to start of the test, and instruments shall be properly calibrated. Specific instrumentation requirements to measure fuel consumption, monitor weather and determine vehicle operations are noted below. The data shall be used to determine acceptance of test results.

6.1.3.1 Fuel Consumption

All fuel consumption instrumentation type, specification and placement shall be documented. A description of the documentation requirements and the information and data collection requirements are contained on Form D2, see appendix D.

This test procedure recommends a gravimetric measurement of the fuel consumed. A flow meter may be used if the flow meter can satisfy the accuracy requirements described in section 5.1.2 and 6.0. Gravimetric fuel measurement instrumentation and equipment are described in Section 5.1.

6.1.3.2 Weather

All weather instrumentation type, specification and placement shall be documented. A description of the documentation requirements and the information and data collection requirements are contained on Form D2, see appendix D. The data collection sampling criteria is presented in section 6.1.3.2.2. All weather data for the test shall be obtained for the day and time that the test was conducted. All weather data must be corrected to a common height above the test start point, see section 6.1.3.2.3. Weather data shall be reviewed following each test run to ensure weather test constraints were not violated.

6.1.3.2.1 On-Track Test Weather Data Collection

It is recommended that weather measurements for an on-track test be obtained at multiple locations along the test track. At a minimum, on-track weather data shall be obtained at one location along the test track. The data sampling for all environmental conditions shall be continuous during a test run and shall not be less than 1 sample / 60 sec for on-track testing.

6.1.3.2.2 On-Road Test Weather Data Collection

On-road test shall collect weather data from one of the following two sources. The first data source option is to obtain data from multiple temporary weather collection systems positioned along the on-road test route by the test staffing. The second option is to obtain data from multiple permanent weather observation stations located in proximity to the test route, such as those located at airport.

Temporary weather collection systems must be positioned at the beginning, mid-point and ending location of the test route. It is recommended that temporary weather data collection system use the 1 sample / 60 sec data sampling rate and duration as described in Section 6.1.3.2.1 for on-track testing. At a minimum the temporary weather data collection system must obtain.

a five (5) min of weather data at the start location, prior to the start of a test run

b. one (1) min of weather data at the mid-point location at the mid-point of a test run

c. five (5) min of weather data at the end location, immediately at the end of a test run

The sampling criteria described for temporary weather data collection system is not applicable to permanent weather observation station data. If permanent weather observation stations are used the criteria listed below must be satisfied.

a. A minimum of 2 weather observation stations must be used. A listing of US permanent weather observation stations may be found at: http://www.ncdc.noaa.gov/oa/climate/stationlocator.html.

b. All permanent weather observation stations must be located within 30 miles (48.3 km) from a point along the on-road test route.

c. The permanent weather observation stations used for the test must be separated from each other by a minimum of 50 miles (80.5 km).

d. If the distances from the test route to each permanent weather observation station differ by less than 20 percent then the test weather data is calculated by a simple average of the data from all stations. If the weather data values obtained from the weather observation stations differ by less than 20 percent then the test weather data is calculated by a simple average of the data from all stations.

If the distances from the test site to each weather observation station differ by greater than 20 percent and the weather parameter values from the weather observation stations differ by more than 20 percent then the test weather data is calculated by using a weighted averaged process that is based upon the distance of a weather observation station from the test route. The weighted averaging is performed by:

1. Calculate the sum of the distances from the test route to each weather station.

   EXAMPLE for two Stations:

   Sum of Distances = (Distance Station 1) + (Distance Station 2)

2. Calculate the weighting scale factor for each weather station by dividing the sum of the distances from step 1 by the distance from the test route to each weather station.

   EXAMPLE for Station 1:

   Scale Factor Station 1 = (Sum of Distances) / (Distance Station 1)

3. Calculate the scaled weather parameter value for a weather station by multiplying the weather station parameter value by the Station weighting scale factor from step 2.

   Scaled Value = (Scale Factor Station 1) X (Weather Value Station 1)

4. Calculate the weighted average weather parameter for the test by dividing the sum of the scaled weather station values from step 3 by the sum of the weighting scale factors from step 2.

   Weighted Average Weather Parameter = (Sum Scaled Values) / (Sum Scale Factors)

6.1.3.2.3 Weather Data Elevation Correction

The weather measurement stations must be located at an elevation distance above the road surface that is greater than 4 feet (1.22 m) and not more than 30 feet (9.14 m). The measurement sensors must be located in an open area and shall not be shielded from above or from the wind in all azimuth angles. The weather measurement device shall be located > 100 feet from the test route or any moving vehicles.

To ensure consistency in the application of the wind speed test criteria all wind speed measurements shall be corrected to an elevation of 10 feet (3.05 m) using the 1/7th power law relationship shown below.

$$VW,10 = VM\ (10/HM)1/7 \quad \text{(Eq. 1)}$$

Where: $V_{W,10}$ is the test reference wind speed at 10 feet above the road surface
V_M is the measured wind speed
H_M is the elevation height for the wind measurement

Listed below are scaling factors, derived from Eq. 1. The user may use the below scaling factors to correct wind speed measurements obtained at a height other than 10 feet to a test reference wind speed at 10 feet above ground level. An example calculation using the scaling factor is shown below.

H_M(ft)	Scale Factor
4 (1.22 m)	1.140
5 (1.52 m)	1.104
6 (1.83 m)	1.076
7 (2.13 m)	1.052
8 (2.44 m)	1.032
9 (2.74 m)	1.015
10 (3.05 m)	1.000
11 (3.35 m)	0.986
12 (3.66 m)	0.974
13 (3.96 m)	0.963

H_M(ft)	Scale Factor
14 (4.27 m)	0.953
15 (4.57 m)	0.944
16 (4.88 m)	0.935
18 (5.49 m)	0.927
20 (6.10 m)	0.919
22 (6.71 m)	0.906
24 (7.32 m)	0.893
26 (7.92 m)	0.882
28 (8.53 m)	0.872
30 (9.14 m)	0.863

Example: A wind speed (V_M) of 10.50 mph (16.9km/h) is obtained at a measurement height (H_M) of 5 feet (1.52 m) above ground level. The corrected wind speed at 10 feet (3.05 m) above ground level is $V_{W,10} = V_M \times H_M = 10.5 \times 1.104 = 11.59$ mph (18.7 km/h).

6.1.3.3 Vehicle Operation

All vehicle operation instrumentation type, specification and placement shall be documented. A description of the documentation requirements and the information and data collection requirements are contained on Form D2, see appendix D.

The data quality demanded by the test procedure requires each Run be executed in a repeatable manner. This can only be accomplished by a close monitoring of vehicle speed throughout the Run. The test procedure requires the use of a high-resolution GPS unit (or device with similar accuracy) capable of measuring road speed within 0.1 mph (.161 km/h). Additionally, the trip average feature of the GPS system can also be used on a test track as an indicator for acceleration rate repeatability from run to run as well as an indicator for final cruise speed between the control and test vehicles.

6.1.4 Driver

All drivers shall be interviewed after each run and their comments noted. A description of the documentation requirements and the information and data collection requirements are contained on Form D3, see appendix D.

Drivers selected should be sufficiently skilled so that test results are not affected by the driver's technique improvement during the test period. Drivers should also have a strong motivation for unbiased results and excellence of test procedure conduct. Drivers shall remain with their vehicles for the complete test.

6.1.5 Observer

All observers (if used) shall be interviewed after each run and their comments noted. A description of the documentation requirements and the information and data collection requirements are contained on Form D3, see appendix D.

Observers may be assigned to each vehicle. Observers, if used, should make and record elapsed time recordings on each run. These calculations are made using stopwatches and mile (km) posts. If mile (km) posts do not exist on the test route, measured miles (km) or landmarks must be identified prior to conducting the test. Observers shall remain with their vehicles for the complete test.

6.1.6 Data Recording Process

All data shall be recorded. A description of the documentation requirements and the information and data collection requirements are contained on data sheets contained in Appendix D. The user is not required to use the forms contained in Appendix D. These forms are provided for convenience only.

6.1.7 Vehicle Warm Up

All warm-up observations shall be documented. A description of the documentation requirements and the information and data collection requirements are contained on Form D4, see appendix D.

All vehicles should be operated at test speeds for not less than one (1) h prior to the start of a test. Warm-up test segments shall be run to insure that the vehicles approach temperature stabilization in all components. If fuel consumption during warm-up is the variable being measured, all vehicles should not be operated for a minimum of 12 h prior to starting each Run.

For vehicles equipped with selective catalytic reduction, particulate filters or other advanced after treatment systems which require periodic regeneration, the test operator must insure the system is at normal operating temperatures and a filter loading is sufficient to avoid regeneration during a run. If a vehicle undergoes an after treatment regeneration event during the warm up event the test operators have two options. Option 1 is to restart the warm up process for all vehicles after the regeneration event has been completed and option 2 is to continue with the warm up until the regeneration process is completed.

To minimize Run variability, it is recommended that during the warm-up process each driver and observer should note the precise location where brakes are used, where shifting of gears occurs, and areas of acceleration and deceleration. These actions will result in greater consistency for each Run during the test process.

6.2 Test Process

This test procedure consists of a Baseline Segment and a Test Segment. A Baseline Segment is comprised of a minimum of three (3) Runs with the Control Vehicle and the unmodified Test Vehicle(s). A Test Segment is comprised of a minimum of three (3) Runs with the Control Vehicle and the modified Test Vehicle(s). The length of each Run shall be ≥ 50 miles (80.5 km).

A Run requires a complete and simultaneous circuit of a specified Test Route by the Control Vehicle and the Test Vehicle(s). All vehicles must be operated during a run with sufficient spacing to minimize aerodynamic vehicle-to-vehicle interference while minimizing differences in ambient environmental conditions experienced by the Test and Control vehicles. The minimum recommended spacing between vehicles is 1500 feet (457.2 m). Each Run must be completed without the occurrence of equipment malfunction, driver malfunction, or a failure to obtain all required weather and operational data. A Run always starts and ends at the same location. Each Run generates one Data Point for the Test Vehicle and one Data Point for the Control Vehicle.

[On-Road Testing ONLY: The length of each Run shall be ≥ 100 miles (161 km). A Run is a complete and simultaneous circuit of a specified Test Route by the Control Vehicle and the Test Vehicle(s) operated with sufficient spacing to minimize aerodynamic interference between the vehicles while minimizing differences in ambient environmental conditions experienced by the Test and Control vehicles shall separate the Control Vehicle and Test Vehicle. The minimum recommended spacing between vehicles is 1500 feet (457.2 m). A closer spacing of not less than 800 feet (243.8 m) may be used for on-road testing to minimize traffic interference. Note, a closer spacing will increase the potential for vehicle-to-vehicle interference effects contaminating the test data*.]*

6.2.1 Baseline Segment

All data from a baseline segment Run shall be recorded. A description of the documentation requirements and the information and data collection requirements are contained on Form D5, see appendix D.

A minimum of three Runs of both the Control Vehicle and Test Vehicle(s) are required for the baseline segment. Each Run must be executed with the Test and Control Vehicles operating simultaneously on the test track with sufficient clean air separation to minimize aerodynamic interference between the lead and following vehicle(s) over the prescribed distance and in accordance with the criteria defined within this procedure.

The Run time for each vehicle is the time from engine start to engine stop or in the case of fuel switching valves, from the time at which the valve is switched to allow fuel flow and to stop fuel flow. Fuel switching valves are a method to change the fuel source from the OEM fuel tank to the test fuel tank. This method may be used provided the fuel lines have been purged of air prior to testing. If switching valves are used, the run elapsed start and stop time coincides with the time of fuel source switching.

The difference in time for the Control and Test vehicles to complete the first Run in the Baseline Segment shall be less than 0.5% of the longest Run time for the vehicles. For example, if the Control Vehicle takes 1 h to complete the first run and the Test Vehicle(s) require less time to complete their first run the Test Vehicle(s) must have completed their first run within 18 s of the Control Vehicle Run time.

Time for each vehicle to complete all subsequent Runs in the Baseline Segment must be within ±0.25% of the time for that specific vehicle to complete it's first Run in the Baseline Segment**.** For example, if the Control Vehicle completes the first Run in 1 h, each subsequent Run by the Control Vehicle in the Baseline Segment must be completed within ±9 sec of the initial Run time. Fuel consumption data shall not be used from a Run that failed to satisfy the Run time repeatability criteria described above.

The following sections describe the preferred approach to the testing process. It is recognized that users may execute the test process with modified /adjusted procedures that satisfy the intent of the method and do not sacrifice data quality.

6.2.1.1 Run Preparation

The Control and all Test Vehicles are moved to the starting point and parked with engines stopped.

Odometers for the Control and Test Vehicles are read and recorded to 0.1 miles (0.161 km).

The collection of weather conditions is initiated in accordance to the requirements described in section 5.2.

The Control and Test Vehicles must be fueled from the same dispenser (fuel source) during the entire test to insure consistent fuel grade and quality.

Portable fuel tanks are topped off, weighed, and the weight recorded as described below.

a. The scale is positioned on a level surface and shielded from the wind.

b. The zero of the scale is verified.

c. A calibration mass of similar weight to a filled portable fuel tank at the start of a Run is used to verify the scale accuracy.

d. The portable fuel tanks are topped off but allowing volume for thermal expansion.

e. The outside surface of the portable tanks is wiped clean of dirt and any fuel residue before they are weighed.

f. The weight of the fuel and tank for each vehicle test tank is determined and recorded.

g. The tanks are installed on their respective vehicles.

6.2.1.2 Run Start

The Control and Test Vehicles must be operated simultaneously on the test track. An interval spacing between the vehicles is used to insure; 1) that one vehicle will not impose an artificial performance limit on the following vehicle and 2) allows tank changes between runs without disproportionate cooling.

NOTE: Run Time is the total elapsed time from engine start to engine stop.

The driver of the Test Vehicle starts the engine and begins driving the test.

Test Vehicle engine start time is recorded.

After 1 min, (a predetermined time to allow sufficient vehicle spacing as described in section 6.2) the driver of the Control Vehicle starts the engine and begins driving the test route.

Control Vehicle engine start time is recorded.

If a pre-determined driving cycle is specified for the test the observer must coach the driver making sure that the vehicle is operated as described in the pre-determined driving cycle.

6.2.1.3 Run End

NOTE: If a regeneration event occurs on either the Control or Test Vehicle during a Run the Run shall be cancelled and repeated. When the regeneration event is complete, the vehicle warm-up procedure should be repeated to achieve thermal stabilization before the next test Run

NOTE: The maximum time between runs is 30 minutes. If the 30-minutes window in exceeded the vehicles must be put through a warm up process.

After completing a test Run the Test Vehicle must stop at the start point. Immediately after full stop of the Test Vehicle the engine is idled for exactly 1 minute then shut down.

Test vehicle stop time is recorded.

Test Vehicle engine stop time is recorded.

Test Vehicle odometer is read and recorded.

After completing the test cycle the Control vehicle must stop at the start point. Immediately after full stop of the Control Vehicle the engine is idled for exactly 1 minute then shut down.

Control vehicle stop time is recorded.

Control Vehicle engine stop time is recorded.

Control Vehicle odometer is read and recorded.

Control and Test Vehicle(s) fuel is measured and recorded as described below.

a. The scale is positioned on a level surface and shielded from the wind and has not been moved from the initial placement prior to the start of the test.

b. The zero of the scale is verified.

c. The portable fuel tanks are removed from each vehicle without spillage of fuel from either the supply or return fuel lines.

d. The outside of the portable tanks is wiped clean of dirt and any fuel residue before they are weighed.

e. The tank and remaining fuel is weighed and recorded.

f. The weight of the tank and fuel is subtracted from the weight of the tank and fuel at the start of the Run the difference is the weight of the fuel consumed per vehicle.

Time for each vehicle to complete a Run in the baseline segment must be within ±0.25% of its initial Baseline Segment Run time. For a Run that requires 1 h to complete, repeatability must be ± 9 s. Fuel consumption data should not be used from Runs that failed to repeat time within ±0.25%. The operational events of these Runs must be identical.

All test data is valid unless invalidated by a documented equipment failure or malfunction or driver error. The reason for invalid data must be recorded and documented on Form D7.

Drivers of all Vehicles should be interviewed between Runs to ascertain any differences in the apparent handling, power, and braking characteristics of their respective vehicles and this information shall be recorded. A description of the documentation requirements and the information and data collection requirements are contained on Form D3. If damage or an event occurred to the vehicle during or between Runs of either the Baseline Segment or the Test Segment, the data should be discarded and documented. A description of the documentation requirements and the information and data collection requirements are contained on Form D7. The Test should be repeated after correcting the problem.

At the end of each run it is recommended that all vehicles be checked for mechanical changes that would affect test results (see items a through m below). At the end of the test day all vehicles must be checked for mechanical changes that would affect test results (see items a through m below). All checks that are completed shall be recorded. A description of the documentation requirements and the information and data collection requirements are contained on Form D4 (see appendix D).

a. Oil pressure and leaks.

b. Air system leaks

b. Coolant temperature and leaks.

c. Exhaust gas temperature.

d. Engine air filter restriction.

e. Electrical load.

f. Tire pressures.

g. Brake dragging (i.e. temperature).

h. Exhaust smoke.

i. Observed ability to maintain selected test speed.

j. Transmission or differential leaks.

k. Intake manifold pressure (turbocharger boost).

l. Number and duration of PDF regeneration events.

m. Exhaust system and after treatment leaks.

Care should be taken to insure that cool-down periods are identical for both vehicles between all Runs. Cool-down periods at start of a test and between Runs should not be more than 10 minutes.

At the conclusion of each Run, all data shall be recorded. A description of the documentation requirements and the information and data collection requirements are contained on Form D5. The next Run is executed by repeating sections 6.2.1.1 through 6.2.1.3.

6.2.2 Test Segment

All test segment test data described on Form D5 and summarized on Form D7 is recorded, see appendix D.

The test segment is executed by first modifying the Test Vehicle with the device, system or equipment being investigated. The Test Segment data is obtained in accordance with the instructions presented for the Baseline Segment described in 6.2.1, 6.2.1.1, 6.2.1.2 and 6.2.1.3.

The Test Segment may be performed prior to the Baseline Segment for purposes of test efficiency.

6.3 Test Data Processing

All test data shall be documented/recorded. A description of the documentation requirements and the information and data collection requirements are contained on Forms D1, D2, D3, D4, D5, D6 and D7, see Appendix D.

All weather data shall be recorded. A description of the documentation requirements and the information and data collection requirements are contained on Form D6.

6.3.1 Test Fuel Consumption Data Recording

All fuel consumption data shall be recorded. A description of the documentation requirements and the information and data collection requirements are contained on Forms D5 and D7, see Appendix D.

6.3.2 Test Fuel Consumption Data Analysis

Fuel consumption data shall be recorded. A description of the documentation requirements and the information and data collection requirements are contained on Forms D5 and D7 is analyzed using the supplied software. The supplied data analysis method is described in Appendix B and a representative analysis is presented in Appendix C.

After Baseline Segment data has been obtained for a minimum of three Runs the Baseline Segment test data is input in to the Baseline Segment table (Table 3) displayed below and analyzed using the supplied software.

TABLE 3 - BASELINE SEGMENT TABLE

Baseline			
Gallons or Lbs			
Run	Test	Control	T/C
1	58.63	59.89	0.9790
2	54.78	55.52	0.9867
3	58.38	59.26	0.9852
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

After Test Segment data has been obtained for a minimum of three Runs the Test Segment test data is input in to the Test Segment table (Table 4) displayed below and analyzed using the supplied software.

TABLE 4 - TEST SEGMENT TABLE

Test			
Gallons or Lbs			
Run	Test	Control	T/C
1	58.68	60.71	0.9666
2	57.46	58.85	0.9764
3	60.00	62.06	0.9668
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

The Test Results are displayed below in Table 5. The information in Table 5 show a 95% confidence interval on the difference in means provided as % improvement and % fuel saved.

TABLE 5 - TEST RESULTS TABLE

Test Result			
	Nominal	Confidence Interval	
Fuel Saved	**1.4%**	**±**	**1.1%**
Improvement	**1.4%**	**±**	**1.1%**

The nominal value shown in Table 5 is determined from an analysis of the measured fuel consumption data only and reflects the measured change in fuel consumed resulting from the modification to the test vehicle.

The confidence interval value in Table 5 is determined from the variation (scatter) in the measured fuel consumption data, relative to the nominal value, and the number of data values obtained. The confidence interval is shown as a ± value about the nominal value. A confidence interval is a range around the nominal value that conveys how precise the nominal value is and indicates the reliability of the nominal value.

If the confidence half-interval value is equal to or greater than the nominal value there is no statistically justified improvement.

A desirable result is to have a confidence half-interval value (column entry) that is significantly less than the nominal value.

6.3.3 Reporting of Test Results

Only calculated values from the supplied software may be used in the reporting of Test results. Test results from the test procedure shall be reported according to the following format and shall contain all information noted below.
(Calculated Percent Change in Fuel Consumed) ± (Percent Confidence Interval of Calculated Value)

@ Mean Vehicle Speed, Vehicle Weight, Gap, Aerodynamic Gap

@ Mean Air Temperature ± change to min and max values

@ Mean Wind Speed ± change to min and max values

EXAMPLE:4% ±2%

@ 65mph (104.4 km/h), 65,000 pounds (29,484 kg), 36 inches (91.44 cm) , 36 inches (91.44 cm)

@ Temp = 70°F (21.1°C) ± 10°F

@ Wind = 3mph (4.83 km/h) ± 2mph (3.22 km/h)

Reporting of the Test results must include sufficient test documentation that defines the test site, measurement equipment, all vehicles, and all devices, systems and equipment being studied. Calibration records for all measurement equipment should be current and maintained with the test report. The information collected should include photographic, sketches, drawings, measurements and descriptive text. The following minimum data are required:

a. Test facility name and location and test date and time.

b. Test track drawing and dimensions.

c. Test track weather data collection sites location and dimensions.

d. Vehicle (truck and trailer) manufacturer, model, and year.

e. Vehicle (truck and trailer) dimensions (length, width, height).

f. Engine manufacturer, model and EPA level.

g. Photographs of each vehicle (truck and trailer) configurations.

h. Photographs of each vehicle at test site.

i. Description and dimensions of vehicle modifications under investigation.

j. Photographs of vehicle modifications under investigation.

k. Time history plot of all weather conditions during test.

l. Test duty cycle description.

7. NOTES

7.1 Marginal indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only

PREPARED BY THE SAE TRUCK AND BUS J1321 REVISION TASK FORCE OF THE SAE TRUCK AND BUS AERODYNAMICS AND FUEL ECONOMY COMMITTEE

APPENDIX A - WEATHER EFFECTS

Environmental factors such as air temperature, barometric pressure, wind speed and wind direction can affect the aerodynamic resistance of all test vehicles. Wind speed and direction will have the largest impact on test data quality. Additionally, wind speed and direction is highly heterogeneous in location and time resulting in significant variation in wind characteristics at a test site and over a test time period. Wind speed and direction will affect each vehicle differently. As a result of these factors it is recognized that all fuel consumption test procedures do not provide wind average effects but are best suited to provide a high quality fuel consumption value over a limited range of wind conditions.

A vehicle operating at a velocity (V_T) will experience a wind velocity (V_W) that impinges on the vehicle at an angle (Φ) this results in a vehicle relative velocity (V) acting at a yaw angle (Ψ) as depicted in figure A1.

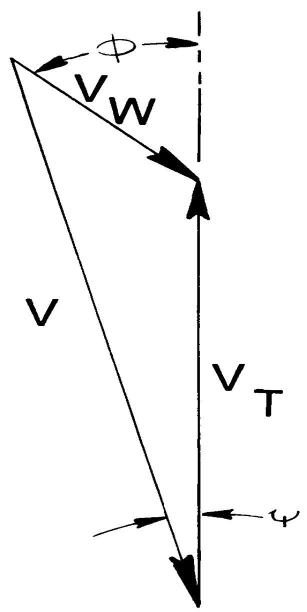

FIGURE A1 – VEHICLE WIND VELOCITY AND YAW DIAGRAM.

Vehicles operating in the continental United States may routinely experience wind speed values in excess of 12 mph, see 2009 Department of Energy (DOE) wind energy data, Wind Energy Resource Atlas of America, DOE/CH 10093-4, Oct. 1986, DE86004442. An analysis of more than 30 years of historical data compiled by the National Oceanic and Atmospheric Administration (NOAA) results in a historical mean wind speed of 7.5 mph (12.1 km/h) at a mid-vehicle elevation distance of 10 feet (3.05 m).

As noted above, the fuel consumption of medium and heavy trucks and buses is highly influenced by environmental conditions and especially by wind speed and direction. Trucks and buses differ from automobiles in that the rate of change of aerodynamic resistance with yaw angle is greatly increased (approximately 10 times higher). Figure A2 shows comparative drag coefficient versus yaw response for various vehicle types. The shape of the yaw curve will vary with vehicle design and aerodynamic treatments. For example, it is possible that an aerodynamic device may reduce drag at low yaw angles and increase drag at higher yaw angles relative to a baseline configuration.

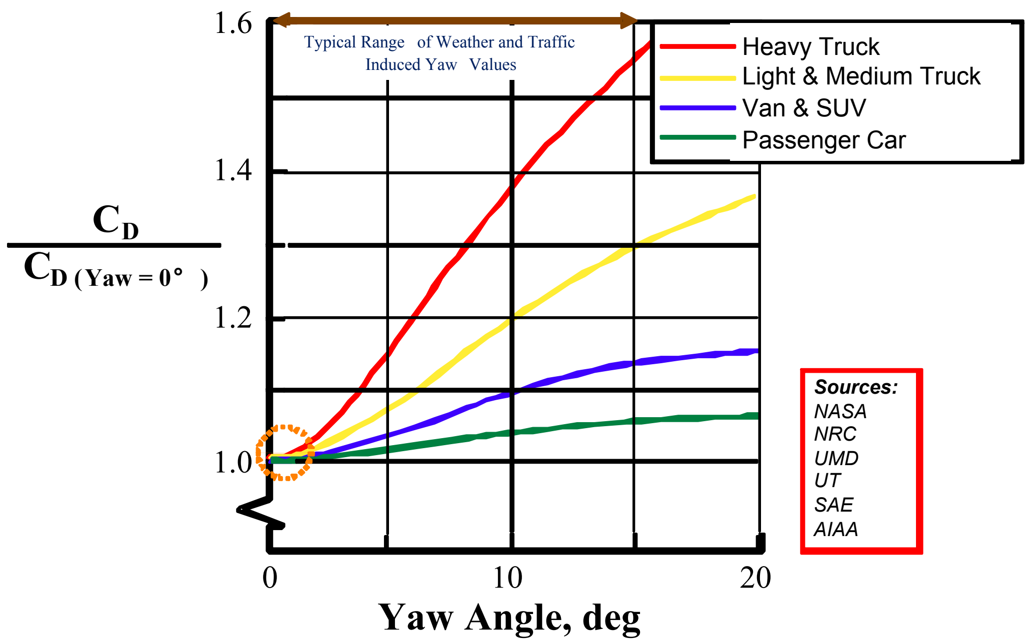

FIGURE A2 - YAW EFFECT ON DRAG COEFFICIENT FOR FAMILIES OF VEHICLES.

The heterogeneous nature of wind with small changes in time and location results in significant differences in wind-induced affects between vehicles on either a test track or public roads. Weather conditions are known to be a primary contributor to test data error such that wind velocity is the leading source of data contamination for the class of trucks and buses covered under this test procedure. Wind will impact the effective speed of the vehicles as well as the yaw angle. These effects can alter the measured fuel consumption values by more than 6%. The error in the measured fuel consumption may be greater if the test vehicles are not identical. Testing in conditions with significant variations in wind speed will negatively impact data quality and limit the ability to assess the effect of vehicle modifications from environmental aerodynamic effects particularly when evaluating devices with sensitivity to high yaw angle changes.

To adequately assess the impact of aerodynamic resistance on fuel consumption for in-service conditions requires the determination of fuel consumption over the full range of wind speeds and directions experienced by the vehicle. The addition of traffic and roadside structure interference adds complexity to the wind effect and may increase the yaw angle. While it is desirable to obtain a wind averaged fuel consumption value it is not possible with this procedure or any other current fuel consumption test procedure due to the limited test mileage and the lack of control over environmental factors.

An approach to improve the understanding of the effect of yaw angle on vehicle performance is to obtain aerodynamic yaw trend data with the SAE J1252 wind tunnel test procedure and to combine these results with fuel consumption data obtained from this procedure for wind velocities less than 5mph.

APPENDIX B - DATA QUALITY – STATISTICAL ANALYSIS APPROACH

Nomenclature

α level of significance
σ population standard deviation
υ degrees of freedom
S sample standard deviation
S_p pooled standard deviation
FF reference statistic
F_o test statistic
n number of runs
H_o null Hypothesis
H_i alternate Hypothesis
t t reference statistic
t_0 t test statistic
T test vehicle
C control vehicle
T/C fuel consumption ratio

This section outlines the statistical tests performed on the J1321 test data at the 95% (α = 5%) confidence level. Multiple runs for both the baseline and test segment are required. The minimum number of runs for each segment is three. Each run of a segment produces a fuel consumption value for both the control vehicle and the test vehicle. The two fuel consumption values obtained from each run are used to generate a test vehicle to control vehicle fuel consumption ratio (T/C ratio) that comprise the samples for the statistical analysis described below. Subscripts with the letter B refer to the baseline segment and those with the letter T, the test segment.

Procedure For Comparative Statistical Testing of Baseline and Test Segment Fuel Consumption

The Statistical Test for Equality of Variance

In order to specify the correct statistical test for the equality of means, it is first necessary to test for equality of variance in the baseline segment T/C ratio samples and test segment T/C ratio samples. These baseline and test segment samples are assumed random observations from normal populations where the hypothesis statement is summarized below. The null hypothesis states that variance in fuel consumption T/C ratio of the test segment (σ_T^2) and baseline segment (σ_B^2) is equal. The alternative hypothesis states the converse, variances are not equal.

H_0: $\sigma_T^2 = \sigma_B^2$
H_1: $\sigma_T^2 \neq \sigma_B^2$

Population variances of the T/C ratio for the test segment (σ_T^2) and baseline segment (σ_B^2) are estimated by sample variances. Sample variances (S^2) for each of the segments are first calculated. The ratio of the sample variances forms the F test statistic, F_0. To prove that the variances are equal, F_0 must fall between the limits defined by the confidence level (1-α) and the number of samples in the test segment (n_T) and baseline segment (n_B). If F_0 is not within the interval, the variances are not equal.

Test Statistic: $$F_0 = \frac{S_T^2}{S_B^2}$$

For Equal Variances: $$F_{\alpha/2, n_T-1, n_B-1} < F_0 < F_{1-\alpha/2, n_T-1, n_B-1}$$

The Statistical Test for Equality of Means – If Variances are Equal

The hypothesis statement for this statistical test is summarized below. The null hypothesis states that mean fuel consumption T/C ratio of the test segment (μ_T) population is equal to the mean fuel consumption T/C ratio of the baseline segment (μ_B). The alternative hypothesis states the converse, the means are not equal.

H_0: $\mu_B = \mu_T$
H_1: $\mu_B \neq \mu_T$

After the J1321 test segment and baseline segment have been completed, compute the test statistic t_0. The numerator is the difference in T/C ratio sample means between the baseline and test segments. The denominator contains a pooled estimate of the T/C ratio sample standard deviation (S_p) and the number of samples (n_B and n_T) in each segment.

$$t_0 = \frac{\overline{y_B} - \overline{y_T}}{S_p \sqrt{\frac{1}{n_B} + \frac{1}{n_T}}}$$

The pooled estimate of the variance is found by weighting the individual variances for the baseline and test segments by their degrees of freedom which is the number of samples less one for the estimation of the mean. The overall degrees of freedom for the J1321 test are $\nu = n_B + n_T - 2$

$$S_p^2 = \frac{(n_B - 1)S_B^2 + (n_T - 1)S_T^2}{n_B + n_T - 2} = \frac{(n_B - 1)S_B^2 + (n_T - 1)S_T^2}{\nu}$$

For the equal variances 2-tailed test with level of significance $\alpha = 0.05$, the difference in means will be significant if $t_0 > t_{\alpha/2,\nu}$ or $t_0 < -t_{\alpha/2,\nu}$ and we will reject H_0 and decide the fuel consumption T/C ratio between the test and baseline segments is different. Otherwise, we fail to reject the null hypothesis and conclude that the average fuel consumption T/C ratio of the vehicles as measured with this J1321 test is equal.

A 95% confidence interval ($\alpha = 0.05$) on the difference in means is calculated using the following formula:

$$(\bar{y}_B - \bar{y}_T) \pm \left(t_{\alpha/2,\nu}\right) S_p \sqrt{\frac{1}{n_B} + \frac{1}{n_T}}$$

The Statistical Test for Equality of Means – If Variances are Not Equal

The hypothesis statement for this test is summarized below. The null hypothesis states that mean fuel consumption T/C ratio of the test segment (μ_T) population is equal to the mean fuel consumption T/C ratio of the baseline segment (μ_B) population. The alternative hypothesis states the converse, the means are not equal.

H_0: $\mu_B = \mu_T$
H_1: $\mu_B \neq \mu_T$

After the J1321 test and baseline segment data have been completed, compute the test statistic t_0. The numerator is the difference in T/C ratio sample means between the baseline and test segments. The denominator contains estimates of the standard deviation of the baseline segment (S_B) and the test segment (S_T) and the number of samples (n_B and n_T) in each segment.

$$t_0 = \frac{\overline{y_B} - \overline{y_T}}{\sqrt{\frac{S_B^2}{n_B} + \frac{S_T^2}{n_T}}}$$

The approximate overall degrees of freedom for the J1321 test are ν, given as:

$$\nu = \frac{\left(\frac{S_B^2}{n_B} + \frac{S_T^2}{n_T}\right)^2}{\frac{\left(\frac{S_B^2}{n_B}\right)^2}{n_B - 1} + \frac{\left(\frac{S_T^2}{n_T}\right)^2}{n_T - 1}}$$

For the unequal variances 2-tailed test with level of significance $\alpha = 0.05$ the difference in means will be significant if, $t_0 > t_{\alpha/2,\nu}$ or $t_0 < -t_{\alpha/2,\nu}$ and we will reject H_0 and decide the average fuel consumption T/C ratio between the test and baseline segments is different. Otherwise, we fail to reject the null hypothesis and decide that the average fuel consumption T/C ratio of the vehicles as measured with this test is equal.

A 95% confidence interval (α=0.05) on the difference in means is calculated using the following formula:

$$(\bar{y}_B - \bar{y}_T) \pm \left(t_{\alpha/2,\nu}\right)\sqrt{\frac{S_B^2}{n_B} + \frac{S_T^2}{n_T}}$$

APPENDIX C - SAMPLE DATA ANALYSIS

Using the Interactive Spreadsheet

A spreadsheet is available to guide the test engineer through the process of conducting a statistical test that meets the criteria described. A description of the steps follows.

1) Conduct a minimum of three baseline segment (BS) runs using the test and control vehicle and enter the gravimetric measurements for fuel consumption in the table marked *Baseline, see Table B1*. The third column is the calculated T/C ratio using the first two columns and will be computed automatically to serve as the baseline data set for the statistical test (shown below).

TABLE B1 - BASELINE SEGMENT TABLE

Baseline			
	Gallons or Lbs		
Run	Test	Control	T/C
1	58.63	59.89	0.9790
2	54.78	55.52	0.9867
3	58.38	59.26	0.9852
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

2) After completion of the baseline segment (BS) runs, the test segment (TS) runs may be conducted. Note that at least three TS runs are required. TS fuel consumption measurements results for the control (unaltered) vehicle and the test vehicle (now modified with the test component) are entered in the first two columns of the Test table B2, see below. The third column is a ratio of the first two columns and will be computed automatically to serve as the TS data set. An example is provided below.

TABLE B2 - TEST SEGMENT TABLE

Test			
	Gallons or Lbs		
Run	Test	Control	T/C
1	58.68	60.71	0.9666
2	57.46	58.85	0.9764
3	60.00	62.06	0.9668
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

3) The user may now check the Test Results in Table B3 to view a 95% confidence interval on the difference in means provided as % improvement and % fuel saved.

The percent "% Fuel Saved" is defined as:

% Fuel Saved = (Avg. Baseline T/C - Avg. Test T/C) ÷ Avg. Baseline T/C

The percent "%Improvement" is defined as:

% Improvement = (Avg. Baseline T/C - Avg. Test T/C) ÷ Avg. Test T/C

An example using the sample data entered in steps 1 and 2 above is given below:

TABLE B3 - TEST RESULTS TABLE

Test Result			
	Nominal	Confidence Interval	
% Fuel Saved	**1.4%**	**±**	**1.1%**
% Improvement	**1.4%**	**±**	**1.1%**

The nominal value shown in Table B3 is determined from an analysis of the measured fuel consumption data only and reflects the measured change in fuel consumed resulting from the modification to the test vehicle.

The confidence interval value in Table B3 is determined from the variation (scatter) in the measured fuel consumption data, relative to the nominal value, and the number of data values obtained. The confidence interval is shown as a ± value about the nominal value. A confidence interval is a range around the nominal value that conveys the precision of the nominal value and indicates the reliability of the nominal value.

If the confidence half-interval value (column entry) is equal to or greater than the nominal value there is no statistically justified improvement.

A desirable result is to have a confidence half-interval value (column entry) that is significantly less than the nominal value.

4) For details on the statistical testing, the informed user may review Appendix B and the tables below.

Summary Stats		
	Baseline	Test
Mean T/C	0.9836	0.9699
Number of Data Points	3	3
Standard Deviations	0.0041	0.0056
Variances	0.0000167	0.0000314
Difference in Means	0.0137	

F-Test for Equal Variances	
Baseline T/C Variance	0.00002
Test T/C Variance	0.00003
F test stat (test/baseline)	1.88013
F low	0.02564
F high	39.00000
Are Variances Equal ?	yes

T-Test with Equal Variances (2-tailed)	
Pooled St dev	0.00490
t-crit	2.776
t-stat	3.418
Is Fuel Economy Improved ?	yes
P-value	0.0268
lower CI bound	0.002569
upper CI bound	0.024787

T-Test with Unequal Variances (2-tailed)	
df (nu)	3.658
t-crit	2.882
t-stat	3.418
Is Fuel Economy Improved ?	yes
P-value	0.0308
lower CI bound	0.002147
upper CI bound	0.025209

APPENDIX D - FORMS

Form D1: Vehicle and Equipment Description
Part 1: Power Units

Testing Organization: ______________________________

Test Date(s): ________________ Test Number: __________

	Control Vehicle	Test Vehicle
Vehicle Unit Number	________	________
Vehicle Make/Model	____/____	____/____
Year	________	________
Number of Axles	________	________
Number of Drive Axles	________	________
Engine Make/Model	________	________
Engine Build Year	________	________
Emission Label Info	________	________
	________	________
Governed Speed @ no load (high idle)	________RPM	________RPM
Rated Power, (bhp)	________hp (kw)	________hp (kw)
Rated Speed	________RPM	________RPM
Peak Torque	________lb-ft	________lb-ft
Peak Torque Speed	________RPM	________RPM
Transmission Make/Model	____/____	____/____
Geared for	________mph (km/h)	________mph (km/h)
	at ________RPM	at ________RPM
	at ________RPM	at ________RPM
Differential Make/Model	____/____	____/____
Differential Ratio	________	________
Steer Tire Type/Make/Model	____/____/____	____/____/____
Steer Tire Pressure (cold)	________psi (kPa)	________psi (kPa)
Drive Tire Type/Make/Model	____/____/____	____/____/____
Drive Tire Pressure (cold)	________	________
5th Wheel Setting (distance fulcrum is ahead or behind bogie centerline)	________in (mm)	________in (mm)

NOTE: 1. In areas where English and metric units are shown circle the unit used.
2. If more than one test vehicle is used repeat this form for the additional test vehicles.

Form D1: Vehicle and Equipment Description
Part 2: Trailer/Body

Testing Organization: ____________________

Test Date(s): ____________ Test Number: ________

	Control Vehicle	Test Vehicle
Vehicle Unit Number	______	______
Vehicle Make/Model	___/___	___/___
Year	______	______
Type (Van, Flatbed, etc...)	______	______
Type of Side	______	______
Type of Corner/Radius	___/___in (mm)	___/___in (mm)
Height	______in (mm)	______in (mm)
Length	______in (mm)	______in (mm)
Width	______in (mm)	______in (mm)
Type Door	______	______
Number of Trailer Axles/Type	___/___	___/___
Truck Trailer Gap	______in (mm)	______in (mm)
Aerodynamic Gap	______in (mm)	______in (mm)
Gross Vehicle Weight	______lbs	______lbs
Differential Ratio	______	______
Tire Type/Make/Model	___/___/___	___/___/___
Tire Pressure (cold)	______psi (kPa)	______psi (kPa)
King Pin Setting	______in (mm)	______in (mm)

NOTE: 1. In areas where English and metric units are shown circle the unit used.
2. If more than one test vehicle is used repeat this form for the additional test vehicles.

Form D1: Vehicle and Equipment Description
Part 3: Devices, Components or Systems that are Incorporated into Control and Test Vehicle Specification

Testing Organization:
Test Date(s):
Test Number:

	Control Vehicle			Test Vehicle		
	No	Yes	Type	No	Yes	Type
Radiator Shutters (on-ff or modulating)						
Engine Cooling Fan Sys (describe below - A)						
Aerodynamic Device (describe below - B)						
Engine Oil						
Transmission Lube						
Differential Lube						
Fuel Heater						
Oil Cooler						
Tag Axle						
Air Lift Axle						
Low Back Pressure Exhaust System						
Other.						

A:
B:

NOTE:
If more than one test vehicle is used repeat this form for the additional test vehicles

Form D1: Vehicle and Equipment Description
Part 4: Detailed Description Vehicle Component or System Modifications Being Tested

Testing Organization:
Test Date(s):
Test Number:

Description/Manufacturer/Part Number/Year:
Dimensions:
Installation Location and Attachment:
Material/Weight/Power Requirements:

Form D2: Instrumentation and Related Equipment Description

Circle the subject area for this form from the categories listed in the following line.

SUBJECT AREAS: Fuel Use / Weather / Vehicle Speed and Spacing / Vehicle Weight and Weight Distribution

Testing Organization:
Test Date(s):
Test Number:

Description/Features/Part Number/Model Number, #1:
Description/Features/Part Number/Model Number, #2:
Description/Features/Part Number/Model Number, #3:
Description/Features/Part Number/Model Number, #4:

Form D3: Driver and Oberserver Comments
Part 1: ___________ Segment, ___________ Vehicle

Testing Organization:
Test Date(s):
Test Number:

_______ Vehicle, Run ____:
DRIVER:
OBSERVER:
_______ Vehicle, Run ____:
DRIVER:
OBSERVER:
_______ Vehicle, Run ____:
DRIVER:
OBSERVER:
_______ Vehicle, Run ____:
DRIVER:
OBSERVER:

Form D4: Vehicle Check, Section 6.1.2
Part 1: Equipment for ____________Vehicle

Testing Organization:
Test Date(s):
Test Number:

	Checked	Accept	Reject	Comment
Engine speed control setting				
Air cleaner element condition/new				
New fuel filters condition/new				
Vehicle clean				
Vehicle damaged / missing body parts				
Cab windows position.				
Accessory load for each vehicle				
Trailer axle alignment checked and proper				
Truck/tractor alignment checked and proper.				
Vehicle properly lubricated				
All fluid levels at prescribed levels.				
Temperature controlled fan operating mode				
Cold tire pressures setting				
Stall check (auto tran and torque converters)				
Exhaust system free of leaks				
Proper brake adjustment.				
Emission after treatment components				

Form D4: Vehicle Check, Section 6.1.7
Part 2: Warm Up for ____________Vehicle

Testing Organization:	
Test Date(s):	
Test Number:	

	Checked	Accept	Reject	Comment
Oil pressure and leaks				
Brake air system leaks				
Coolant temperature and leaks				
Exhaust gas temperature				
Engine air filter restriction				
Electrical load.				
Tire pressures				
Brake dragging (i.e. temperature).				
Exhaust smoke				
Observed ability to maintain selected test speed				
Transmission or differential leaks				
Intake manifold pressure (turbocharger boost)				
After treatment condition, state of DPF loading and regeneration				
Check diagnostic caution and warning signals/alarms				

Form D4: Vehicle Check, Section 6.2.1.3
Part 3: Between Runs _______________Vehicle

Testing Organization:	
Test Date(s):	
Test Number:	

	Checked	Accept	Reject	Comment
Oil pressure and leaks				
Brake air system leaks				
Coolant temperature and leaks				
Exhaust gas temperature				
Engine air filter restriction				
Electrical load.				
Tire pressures				
Brake dragging (i.e. temperature).				
Exhaust smoke				
Observed ability to maintain selected test speed				
Transmission or differential leaks				
Intake manifold pressure (turbocharger boost)				
After treatment condition, state of DPF loading and regeneration				
Check diagnostic caution and warning signals/alarms				

Form D4: Vehicle Check, Section 6.2.1.3
Part 4: End of Test Day __________Vehicle

Testing Organization:
Test Date(s):
Test Number:

	Checked	Accept	Reject	Comment
Oil pressure and leaks				
Brake air system leaks				
Coolant temperature and leaks				
Exhaust gas temperature				
Engine air filter restriction				
Electrical load.				
Tire pressures				
Brake dragging (i.e. temperature).				
Exhaust smoke				
Observed ability to maintain selected test speed				
Transmission or differential leaks				
Intake manifold pressure (turbocharger boost)				
After treatment condition, state of DPF loading and regeneration				
Check diagnostic caution and warning signals/alarms				

Form D5: ____________ Segment Data Collection

Part 1: Segment Run #_____

Testing Organization:	Test Number:
Test Date/Time:	
Driver:	Observer:
Power Unit #:	Trailer #:
Test Site/Type:	
Duty Cycle Description:	
Segment Run #:	Scale Check Weight:

Segment Run Acceptance Criteria

1. Run Time for each vehicle must be within 0.25% of a vehicle's Segment Run #1 Time.
2. All wind speed and wind temperature constraints must be satisfied
3. No equipment failure or malfunction or drive error.
4. If the three criteria described above are not satisfied the Run must be repeated.

Vehicle Data

Control Vehicle	Fuel Weight	Engine Time	Vehicle Time	Odometer
Start				
Stop				
Change				
	Fuel Used		Run Time	

Test Vehicle	Fuel Weight	Engine Time	Vehicle Time	Odometer
Start				
Stop				
Change				
	Fuel Used		Run Time	

Weather Data

Wind Data @ 10 ft	Mean Wind Speed	Min Wind Speed	Max Wind Speed	Variation in Run Wind Speed	Variation in Segment Wind Speed	Variation in Test Wind Speed
Measured						
Constraint	≤12 mph	na	≤15 mph	≤5 mph	≤5 mph	≤5 mph

Temperature Data	Min Temp	Max Temp	Variation in Run Temp	Variation in Segment Temp	Variation in Test Temp.
Measured					
Constraint	≥40 °F	≤100 °F	≤30 °F	≤30 °F	≤30 °F

Form D5: ____________ Segment Data Collection
Part 2: Segment Run #_____ (continuation sheet)

Testing Organization:	Test Number:
Test Date/Time:	
Driver:	Observer:
Power Unit #:	Trailer #:
Test Site/Type:	
Duty Cycle Description:	
Segment Run #:	Scale Check Weight:

Segment Run Acceptance Criteria

1. Run Time for each vehicle must be within 0.25% of a vehicle's Segment Run #1 Time.
2. All wind speed and wind temperature constraints must be satisfied
3. No equipment failure or malfunction or drive error.
4. If the three criteria described above are not satisfied the Run must be repeated.

Test Vehicle Data

Test Vehicle	Fuel Weight	Engine Time	Vehicle Time	Odometer
Start				
Stop				
Change				
	Fuel Used		Run Time	

Test Vehicle	Fuel Weight	Engine Time	Vehicle Time	Odometer
Start				
Stop				
Change				
	Fuel Used		Run Time	

Weather Data

Wind Data @ 10 ft	Mean Wind Speed	Min Wind Speed	Max Wind Speed	Variation in Run Wind Speed	Variation in Segment Wind Speed	Variation in Test Wind Speed
Measured						
Constraint	≤12 mph	na	≤15 mph	≤5 mph	≤5 mph	≤5 mph

Temperature Data		Min Temp	Max Temp	Variation in Run Temp	Variation in Segment Temp	Variation in Test Temp.
Measured						
Constraint		≥40 °F	≤100 °F	≤30 °F	≤30 °F	≤30 °F

Form D6: Test Weather Data Summary

Testing Organization:	Test Number:
Test Date/Time:	
Driver:	Observer:
Power Unit #:	Trailer #:
Test Site/Type:	
Duty Cycle Description:	

Weather Data

Baseline Segment	Mean Wind Speed @ 10 ft	Min Wind Speed @ 10 ft	Max Wind Speed @ 10 ft	Variation in Wind Speed @ 10 ft	Min Temp	Max Temp	Variation in Temp	Average Humidity	Average Barometric Pressure
Run #1									
Run #2									
Run #3									
Run #4									
Run #5									
Segment									
Constraint	≤12 mph	na	≤15 mph	≤5 mph	≥40 °F	≤100 °F	≤30 °F	na	na

Test Segment	Mean Wind Speed @ 10 ft	Min Wind Speed @ 10 ft	Max Wind Speed @ 10 ft	Variation in Wind Speed @ 10 ft	Min Temp	Max Temp	Variation in Temp	Average Humidity	Average Barometric Pressure
Run #1									
Run #2									
Run #3									
Run #4									
Run #5									
Segment									
Constraint	≤12 mph	na	≤15 mph	≤5 mph	≥40 °F	≤100 °F	≤30 °F	na	na

Form D7: Test Fuel Use Summary

Testing Organization:		
Test Date/Time:		
Driver:	Observer:	
Power Unit #:	Trailer #:	
Test Site/Type:		
Duty Cycle Description:		

Test Run Data Acceptance Criteria

1. All Run Time criteria must be satisfied
2. All wind speed and wind temperature constraints must be satisfied
3. No equipment failure or malfunction or drive error.
4. Test Run data is valid if the three criteria listed above are satisfied.

Baseline Segment	Valid Run	Test (T) Vehicle Fuel Used	Control (C) Vehicle Fuel Used	T/C Ratio
Run #1				
Run #2				
Run #3				
Run #4				
Run #5				

Identify Run and describe equipment failure/malfunction or driver error:

Test Segment	Valid Run	Test (T) Vehicle Fuel Used	Control (C) Vehicle Fuel Used	T/C Ratio
Run #1				
Run #2				
Run #3				
Run #4				
Run #5				

Identify Run and describe equipment failure/malfunction or driver error: