

Assessment of Evaluation Method Types to Determine Energy Efficiency of Multi-Vehicle Systems

RATIONALE

Automated vehicles are being developed as a means to provide safer and more efficient transportation services. These vehicle types can also be used in multi-vehicle platoons in automated driving. As the capabilities of these vehicle types differ from conventional vehicles, a need exists for standards to evaluate the operational characteristics of multi-vehicle systems. The focus of this document are on-road trucks and buses with GVWR of more than 10000 pounds (4535 kg). To support and guide the development of new standards relevant to these vehicle system types, a review and assessment of relevant isolated-vehicle standards and relevant technology areas are required.

FOREWORD

The increased demand for greater fuel efficiency, improved freight efficiency and reduced emissions coupled with major advancements in automation, connectivity, powertrain systems, low rolling resistance tires, aerodynamics, and system integration have led to a growing need for engineering evaluation methods for determining the impact of various technologies on fuel consumption, emissions and freight efficiency of multi-vehicle systems. To address these needs the SAE committee agreed to develop this document that will guide the future evaluation of multi-vehicle commercial vehicle systems. The committee and task force that developed this document were comprised of truck manufacturers, test facility experts, engine manufacturers, technology developers and technical experts from academia and industry. This document draws from a large body of test data, input from major testing laboratories and industry groups to provide:

1. An assessment of existing isolated-vehicle test and evaluation standards related to greater fuel efficiency, improved freight efficiency and reduced emissions for single- and multi-vehicle systems.
2. An assessment of test and evaluation methods and technologies that impact the fuel efficiency, freight efficiency and emissions of automated single- and multi-vehicle systems.
3. Guidelines for the selection and use of tests, methods and technologies that impact the evaluation or measurement of fuel efficiency, freight efficiency and emissions of automated single- and multi-vehicle systems.
4. Guidelines for the development of tests and evaluations of technologies that impact the fuel efficiency, freight efficiency and emissions of automated single- and multi-vehicle systems.

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1. SCOPE

This document provides an assessment of current engineering test and simulation standards and methods used to determine the fuel efficiency, freight efficiency and emissions of single-vehicle systems comprised primarily of on-road trucks and buses with GVWR of more than 10000 pounds (4535 kg). This document provides guidance on the applicability and use of each test and simulation standard, method and technology discussed for multi-vehicle systems.

1.1 Purpose

This document provides an assessment of existing engineering testing and simulation standards for fuel efficiency and related technologies of multi-vehicle systems that could be enabled by automated technologies. This document also provides guidelines for the use of these current standards as well as the development of new standards for multi-vehicle systems.

1.2 Limitations and Rules

The operational characteristics of a multi-vehicle system cannot be replicated within the requirements of existing standards developed for conventional single vehicles. This document is only intended provide an assessment of the existing test methods for their applicability towards multi-vehicle systems.

1.3 Document Use

The operational characteristics of a multi-vehicle system cannot be replicated within the requirements of existing standards developed for conventional single vehicles. This document is only intended to provide an assessment of existing standards and be used as a basis for the development of multi-vehicle system test protocol.

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

2. REFERENCES

2.1 Applicable Documents

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 J1025	Test Procedures for Measuring Truck Tire Revolutions Per Kilometer/Mile
SAE J1252	SAE Wind Tunnel Test Procedure for Trucks and Buses
SAE J1263	Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques
SAE J1264	Joint RCCC/SAE Fuel Consumption Test Procedure (Short Term In-Service Vehicle) Type 1
SAE J1269	Rolling Resistance Measurement Procedure for Passenger Car, Light Truck, and Highway Truck and Bus Tires
SAE J1321	Fuel Consumption Test Procedure - Type II)
SAE J1526	SAE Fuel Consumption Test Procedure (Engineering Method)
SAE J2084	Aerodynamic Testing of Road Vehicles – Testing Methods and Procedures
SAE J2188	Commercial Truck and Bus SAE Recommended Procedure for Vehicle Performance Prediction and Charting

- SAE J2263 Road Load Measurement Using Onboard Anemometry and Coastdown Techniques
- SAE J2452 Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance
- SAE J2711 Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles
- SAE J2966 Guidelines for Aerodynamic Assessment of Medium and Heavy Commercial Ground Vehicles Using Computational Fluid Dynamics
- SAE J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
- SAE Paper No. 810025 "Transit Bus Fuel Economy Test", H. H. Buckel

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.

Wood, R.M.; Reynolds Number Impact on Commercial Vehicle Aerodynamics and Performance. *SAE Int. J. Commer. Veh.* 8(2):590-667, 2015, doi:10.4271/2015-01-2859.

Wood, R., A Review of Reynolds Number Effects on the Aerodynamics of Commercial Ground Vehicles. *SAE Int. J. Commer. Veh.* 5(2):628-639, 2012, doi:10.4271/2012-01-2045.

Doane, S., Landman, D., and Wood, R.M.; A Computer Simulation of the Effect of Wind on Heavy Truck Fuel Consumption Testing, SAE 2010-01-2039.

Landman, D., Wood, R., Seay, W., and Bledsoe, J., Understanding Practical Limits to Heavy Truck Drag Reduction. *SAE Int. J. Commer. Veh.* 2(2):183-190, 2010, doi:10.4271/2009-01-2890.

2.1.2 TMC Publications

- TMC RP 1102A TMC In-Service Fuel Consumption Test Procedure-Type II (2014)
- TMC RP 1103A TMC In-Service Fuel Consumption Test Procedure—Type III (2015)
- TMC RP 1109B Type IV Fuel Economy Test Procedure (2012)

2.1.3 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

- 40 CFR Part 600 Fuel Economy and Greenhouse Gas Exhaust Emissions of Motor Vehicles
- 40 CFR Part 1037 Control of Emissions from New Heavy-Duty Motor Vehicles
- 40 CFR Part 1065 Engine Test Procedures
- 40 CFR Part 1066 Vehicle Testing Procedures

2.1.4 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

- ISO 18164:2005(E) Passenger car, truck, bus and motorcycle tyres -- Methods of measuring rolling resistance
- ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories

ISO 28580:2009 Passenger car, truck and bus tyres -- Methods of measuring rolling resistance -- Single point test and correlation of measurement results

2.1.5 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 Publications

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

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 J1594 Vehicle Aerodynamics Terminology

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

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms

ADS	Automated Driving System
ARB	California Air Resource Board, also CARB
ATA	American Trucking Association
CARB	California Air Resource Board, also ARB
CC	Cost Criteria
CDQAC	Combined Data Quality Assessment Criteria
CFR	United States Code of Federal Regulations
DEF	Diesel Exhaust Fluid
DDT	Dynamic Driving Task
DQAC	Data Quality Assessment Criteria
EPA	United States Environmental Protection Agency
EV	Electric Vehicle
GEM	EPA's Greenhouse Gas Emissions Model
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HEV	Hybrid Electric Vehicle