SAE Standards Development

(J1711 PHEV, J2841 Utility Factor Definition, J1715 HEV Terminology)

2010 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

June 09, 2010

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Argonne National Laboratory

Sponsored by Lee Slezak

U.S. Department of Energy

Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Project ID # VSS026

Overview

Timeline

- Start: Late 2006
- End: March 2010
- 100% Complete

Barriers

- Barriers addressed
  - Address codes and standards needed to enable wide-spread adoption of electric-drive transportation technologies.

Budget

- Total project funding
  - $0k in FY08
    (included in benchmarking activity)
  - $300k in FY09
  - $150k in FY10
- Benchmarking program heavily leveraged *(standards activity not possible without ANL benchmark testing program)*

Partners

- ANL staff is Chair of J1711
- Task Force includes experts from, Toyota, Honda, Ford, Chrysler, GM, Nissan, JARI, Mitsubishi, NREL, EPA, CARB, Environment Canada

Relevance: Industry and Certification Bodies Will Use This Updated PHEV Test Procedure

"The choice of the ways to test and compare fuel economy has never been more critical - or more complex " **– Peter Savagian,** Engineering Director, GM Powertrain in address to SAE Congress, April 2010

Updated PHEV test procedure allows testing any conceivable PHEV concept with level playing field, no technology forcing

- Original J1711 components required many changes and updates to match contemporary PHEV designs
- EPA will adopt features in balloted J1711 document
- J1711 is applicable to Mileage Label and CAFE
- J2841 will be sited by anyone doing fuel consumption studies of PHEVs

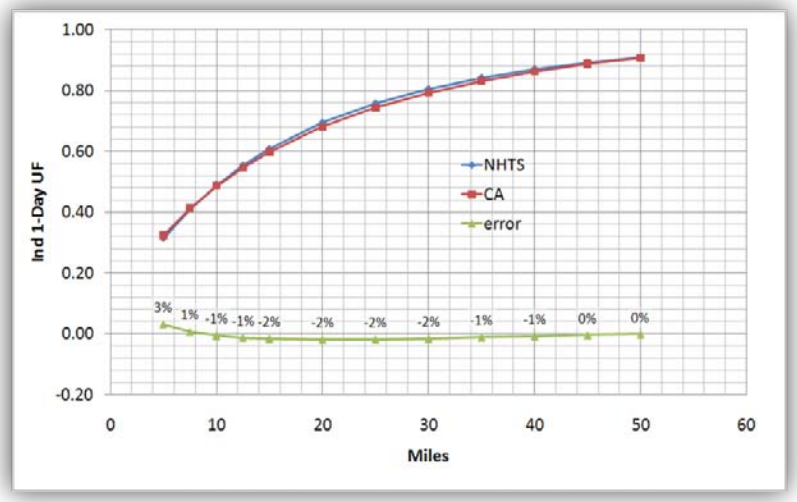
Approach: Leverage PHEV Benchmarking Activities, Find Robust, Unbiased Methodology

- Objective:
  - Update conventional hybrid procedures where needed
  - Develop test procedures resulting in proper measurement of both electricity and fuel consumption over 5 standard EPA cycles
  - Harmonize as much as possible with the numerous organizations also developing PHEV test procedures
- Approach:
  1. ANL chair J1711 Task Force as arbiter of competing OEM interests
  2. Test as many available PHEV prototypes, find issues (2006 to 2008)
  3. Gather ideas and methods (2008 to 2009)
  4. Investigate short-cut methods (2008, objective tabled for a few years)
  5. Sensitivity studies into many test details requiring decisions (2008 to 2009)
     - test pause lengths, charging details, soak details for SC03 and Cold UDDS
  6. Final Concept drafted, meetings every 2 weeks (2009)
  7. Concept written into J1711 document (late 2009)
  8. Pre-ballot periods, JARI, ISO, ECE (early 2010)
  9. Sent to ballot (March 2010)

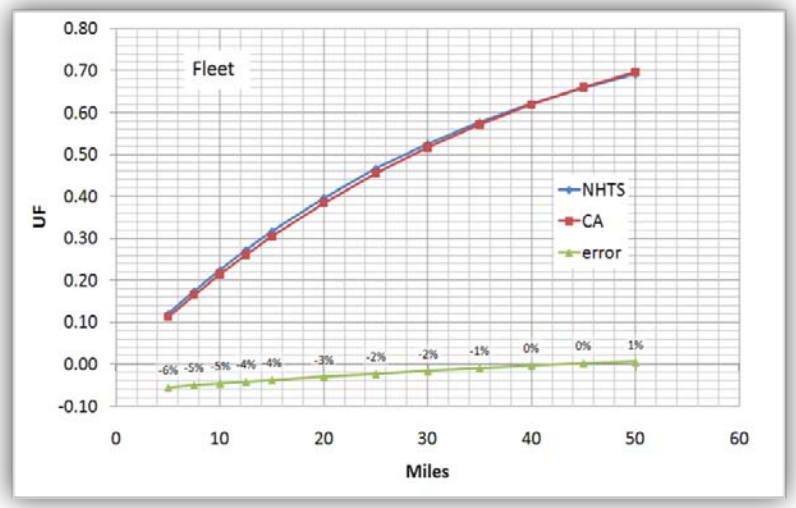
New Accomplishment: "Multi-Day Individual Utility Factor" Completed

- UF's determine the appropriate mix of depleting operation
- "Individual" UF is vehicle-weighted, not miles-weighted
- DOT NHTS survey does not have multi-day data to find this information
- Multi-day can be calculated from Commute Atlanta (CA), a two year study
- ANL managed entire sub-contract and analysis involving many parties
  - Key metrics of Commute Atlanta data matched NHTS data eliminating the need to employ tricky scaling techniques

NHTS vs CA Data – Ind 1-Day UF

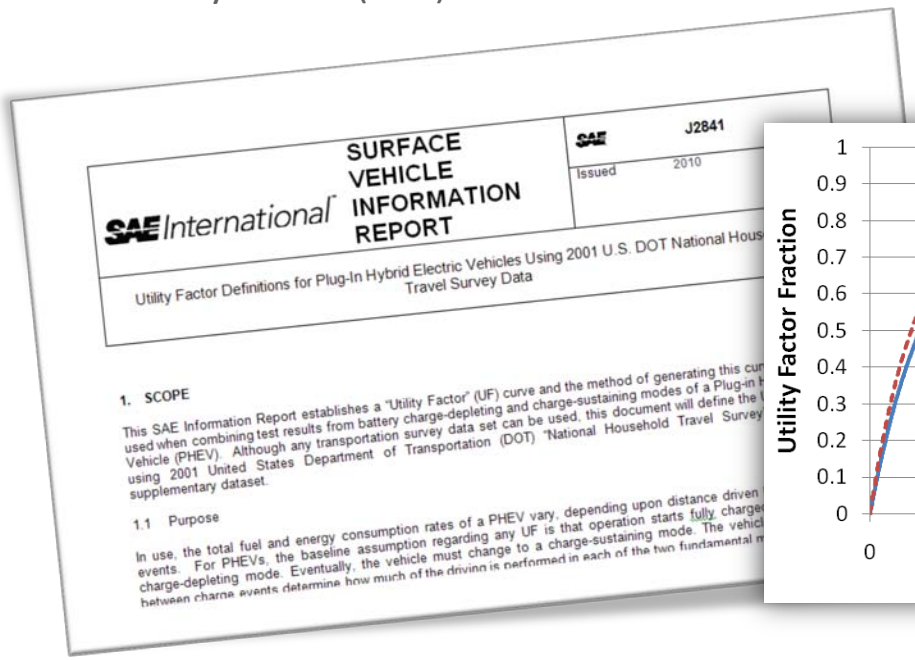


NHTS vs CA Data – Fleet UF



New Accomplishment: J2841 Re-Written With "Multi-Day Individual Utility Factor (MDIUF)"
And Guidance for City/Highway Specific UF Curves

- Document sponsored by ANL staff, re-written to include MDIUF and City/Hwy specific UF data
- The MDIUF alternative may be helpful in conveying average consumer experience with a particular PHEV
  - Long distance drivers reduce the apparent utility of depleting operation in the Fleet Utility Factor (FUF)


SAE International

SURFACE VEHICLE INFORMATION REPORT

SAE J2841

Issued 2010

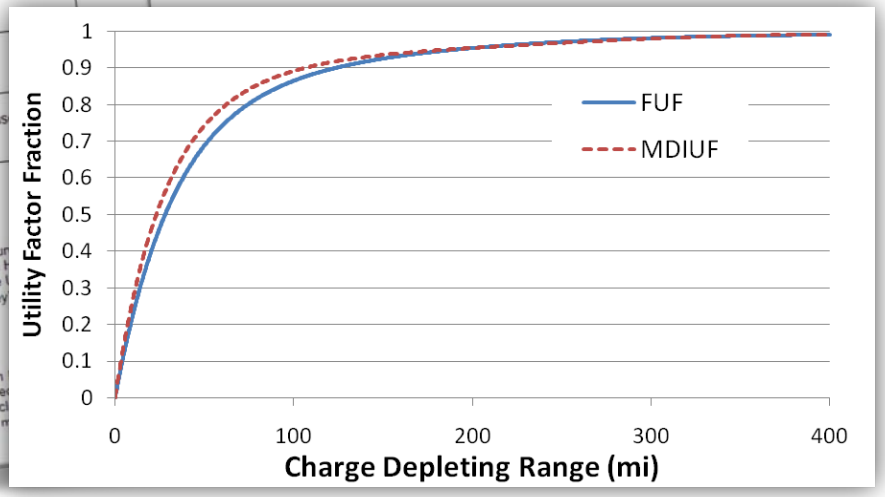
Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using 2001 U.S. DOT National Household Travel Survey Data

1. SCOPE

This SAE Information Report establishes a "Utility Factor" (UF) curve and the method of generating this curve used when combining test results from battery charge-depleting and charge-sustaining modes of a Plug-in Hybrid Electric Vehicle (PHEV). Although any transportation survey data set can be used, this document will define the UF curve using 2001 United States Department of Transportation (DOT) "National Household Travel Survey" as the supplementary dataset.

1.1 Purpose

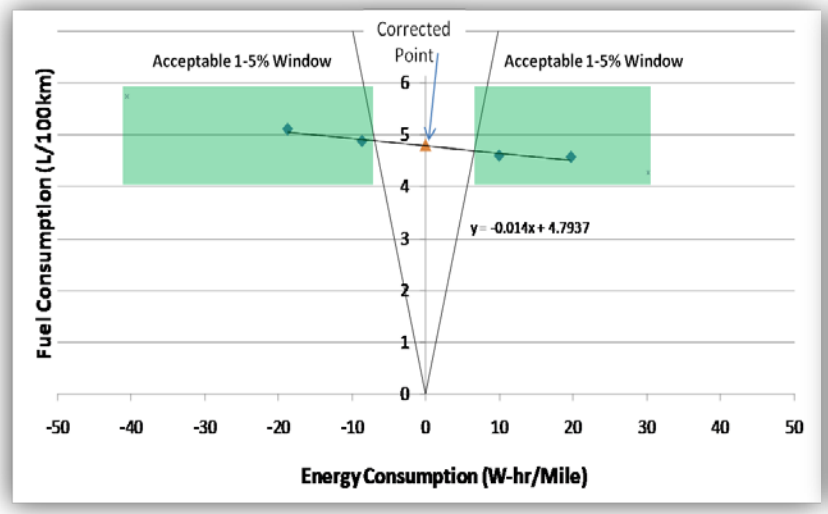
In use, the total fuel and energy consumption rates of a PHEV vary, depending upon distance driven between charge events. For PHEVs, the baseline assumption regarding any UF is that operation starts fully charged in charge-depleting mode. Eventually, the vehicle must change to a charge-sustaining mode. The vehicle

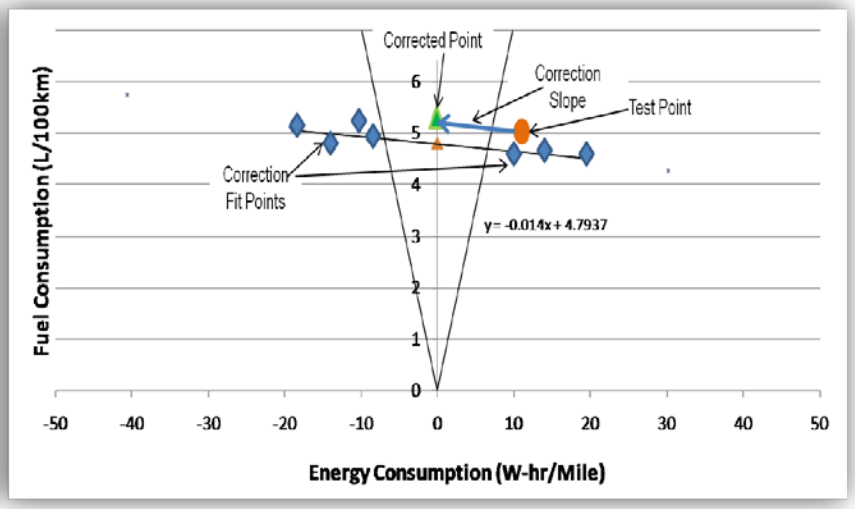


New Accomplishment: Finally, A Rigorous Analysis Defining SOC Corrections

Charge-balanced results from PHEV testing in CS mode is a challenge, new J1711 offers more sophisticated instruction in utilizing SOC corrections:

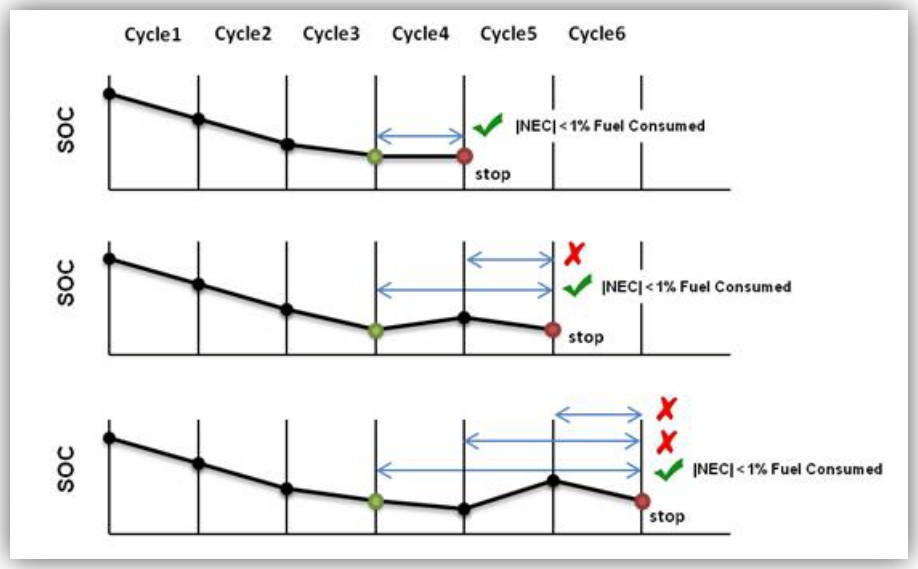
- Many SOC correction proposals in the literature, but committee decided a robust concept derived from real data with a contextual error analysis was needed
- ANL provided error analysis
  - Monte Carlo methods
  - Several years of HEV testing from dozens of productions HEVs
- A simple approach was developed satisfying two test scenarios
  - Find SOC = 0 regression result by specifying necessary criteria of 4 (or more) tests
  - Valid line SOC regression used to correct a single test (use in certification or development testing)





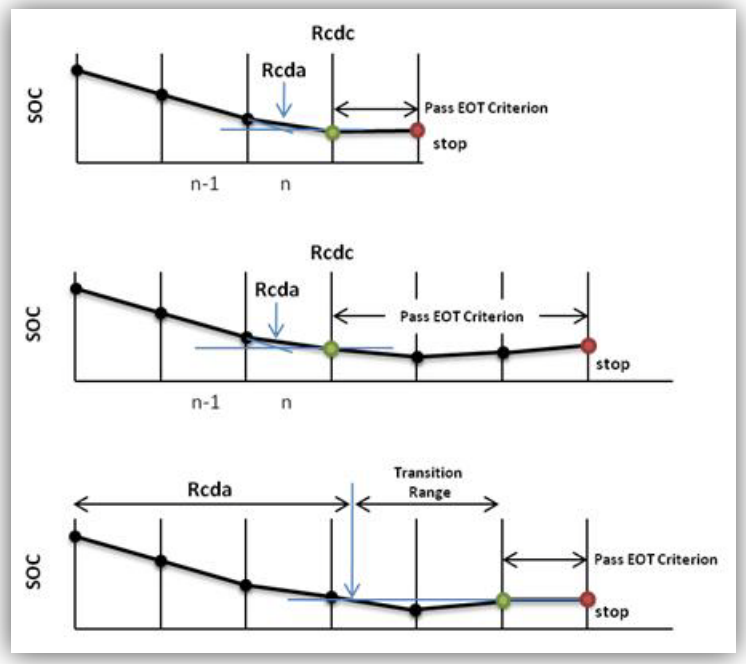
New Accomplishments: Harmonized Charge Depleting Range and End of Test Criterion

- Robust End of Test Criterion was focus of extensive investigation, research and harmonization



Challenge: Unusual SOC behavior shall not invalidate methods or result in undesired anomalies

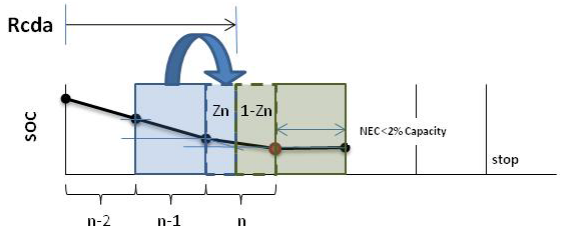
- Charge-depleting range definition made compatible with end of test



New Accomplishment: Alternative Results Calculations (Not Using UFs)

J1711 Appendix offers a CD result associated with a calculated depleting range

- Single result from the UF method may not satisfy all stakeholders
- Method developed that splits transition cycle into depleting and sustaining segments based upon SOC trends
- The depleting consumption rate (fuel and electricity) is associated with a precisely calculated range



- Rcda: the distance sum of the CD cycles plus the estimated fraction of cycle *n* that is charge depleting (Zn*Dn)
- Zn Fuel: cycle *n*-1 depleting mode is imposed upon the Zn portion of cycle n
- Zn Electricity: all energy consumed in cycle n is given to Zn portion of cycle n

Example Description:

180 MPG and 120Wh/mi
After 36 Miles,
52 MPG

or for EREV PHEV:
260Wh/mi
After 40 Miles,
45 MPG

New Accomplishment: J1715 HEV Terminology Document Updating

- APRF staff doing research into HEV technology since 1989
- ANL adding input to reconcile recent terminology compared to terms used in the past literature
  - ANL provided memo citing “range-extender” usage in past literature
- ANL staff sits on ISO committee now doing similar document
- ANL harmonizing terms used in J1711 document
- **Status**: Still under development

SAE International

SURFACE VEHICLE INFORMATION REPORT

SAE J1715 FEB2008

Issued 1994-04
Revised 2008-02

Superseding J1715 JUN2000

(R) Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology

RATIONALE

Document revised to include Hybrid Electric Vehicle terminology. Previous document only referenced Electric Vehicle

FOREWORD

This document is an ongoing effort to provide the technical community with the terminology used most frequently in the Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) industry.

1. SCOPE

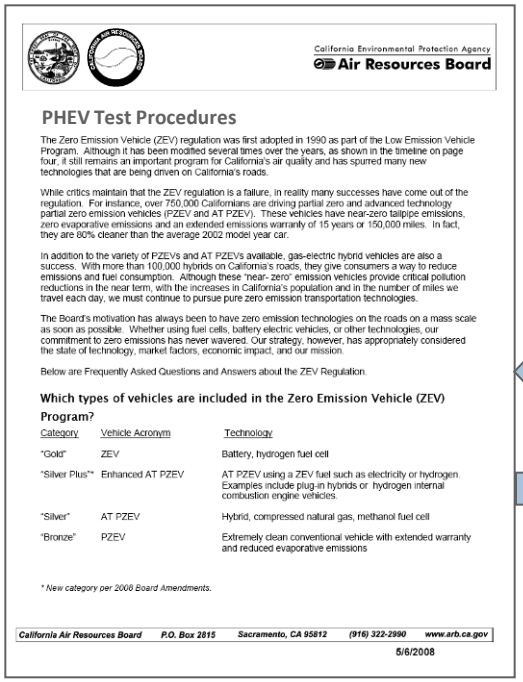
This SAE Information Report contains definitions for HEV and EV terminology. It is intended that this document be a resource for those writing other HEV and EV documents, specifications, standards, or recommended practices.

1.1 Purpose

The purpose of this document is to provide a record of commonly used terminology established by the technical community involved with writing practices and information reports for HEVs and EVs .

Collaborations

- EPA, DOT Will Reference SAE Standard
- CARB and J1711 Procedures Made Compatible
- ISO and J1711 Collaborate



California Environmental Protection Agency
Air Resources Board

PHEV Test Procedures

The Zero Emission Vehicle (ZEV) regulation was first adopted in 1990 as part of the Low Emission Vehicle Program. Although it has been modified several times over the years, as shown in the timeline on page four, it still remains an important program for California's air quality and has spurred many new technologies that are being driven on California's roads.

While critics maintain that the ZEV regulation is a failure, in reality many successes have come out of the regulation. For instance, over 750,000 Californians are driving partial zero and advanced technology partial zero emission vehicles (PZEV and AT PZEV). These vehicles have near-zero tailpipe emissions, zero evaporative emissions and an extended emissions warranty of 15 years or 150,000 miles. In fact, they are 80% cleaner than the average 2002 model year car.

In addition to the variety of PZEVs and AT PZEVs available, gas-electric hybrid vehicles are also a success. With more than 100,000 hybrids on California's roads, they give consumers a way to reduce emissions and fuel consumption. Although these "near- zero" emission vehicles provide critical pollution reductions in the near term, with the increases in California's population and in the number of miles we travel each day, we must continue to pursue pure zero emission transportation technologies.

The Board's motivation has always been to have zero emission technologies on the roads on a mass scale as soon as possible. Whether using fuel cells, battery electric vehicles, or other technologies, our commitment to zero emissions has never wavered. Our strategy, however, has appropriately considered the state of technology, market factors, economic impact, and our mission.

Below are Frequently Asked Questions and Answers about the ZEV Regulation.

Which types of vehicles are included in the Zero Emission Vehicle (ZEV) Program?

Category	Vehicle Acronym	Technology
"Gold"	ZEV	Battery, hydrogen fuel cell
"Silver Plus"*	Enhanced AT PZEV	AT PZEV using a ZEV fuel such as electricity or hydrogen. Examples include plug-in hybrids or hydrogen internal combustion engine vehicles.
"Silver"	AT PZEV	Hybrid, compressed natural gas, methanol fuel cell
"Bronze"	PZEV	Extremely clean conventional vehicle with extended warranty and reduced evaporative emissions

** New category per 2008 Board Amendments.*

California Air Resources Board P.O. Box 2815 Sacramento, CA 95812 (916) 322-2990 www.arb.ca.gov

5/6/2008

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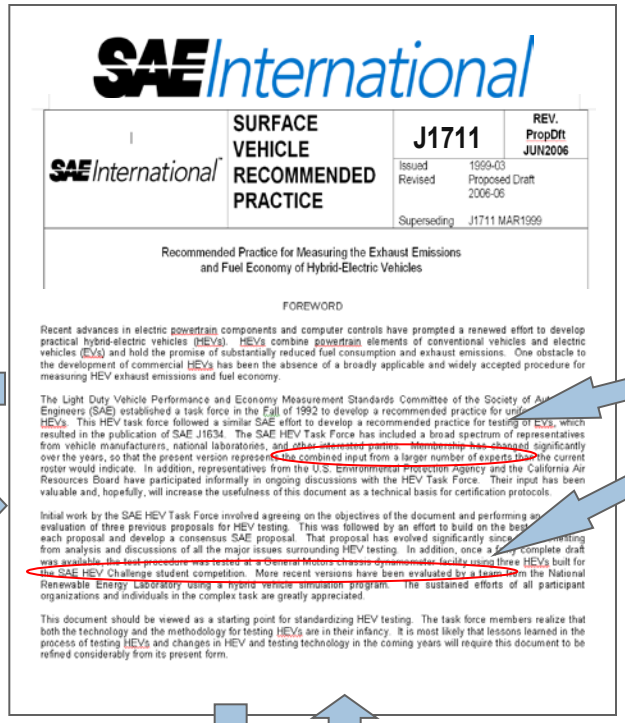

SAE International

SAE International | SURFACE VEHICLE RECOMMENDED PRACTICE | J1711 | REV. PropDft JUN2006

Issued 1999-03
Revised Proposed Draft 2006-06
Superseding J1711 MAR1999

Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles

FOREWORD

Recent advances in electric powertrain components and computer controls have prompted a renewed effort to develop practical hybrid-electric vehicles (HEVs). HEVs combine powertrain elements of conventional vehicles and electric vehicles (EVs) and hold the promise of substantially reduced fuel consumption and exhaust emissions. One obstacle to the development of commercial HEVs has been the absence of a broadly applicable and widely accepted procedure for measuring HEV exhaust emissions and fuel economy.

The Light Duty Vehicle Performance and Economy Measurement Standards Committee of the Society of Automotive Engineers (SAE) established a task force in the Fall of 1992 to develop a recommended practice for unified HEVs. This HEV task force followed a similar SAE effort to develop a recommended practice for testing of EVs, which resulted in the publication of SAE J1634. The SAE HEV Task Force has included a broad spectrum of representatives from vehicle manufacturers, national laboratories, and other interested parties. Membership has changed significantly over the years, so that the present version represents the combined input from a larger number of experts than the current roster would indicate. In addition, representatives from the U.S. Environmental Protection Agency and the California Air Resources Board have participated informally in ongoing discussions with the HEV Task Force. Their input has been valuable and, hopefully, will increase the usefulness of this document as a technical basis for certification protocols.

Initial work by the SAE HEV Task Force involved agreeing on the objectives of the document and performing an evaluation of three previous proposals for HEV testing. This was followed by an effort to build on the best of each proposal and develop a consensus SAE proposal. That proposal has evolved significantly since its beginning from analysis and discussions of all the major issues surrounding HEV testing. In addition, once a fairly complete draft was available, the test procedure was tested at a General Motors chassis dynamometer facility using three HEVs built for the SAE HEV Challenge student competition. More recent versions have been evaluated by a team from the National Renewable Energy Laboratory using a hybrid vehicle simulation program. The sustained efforts of all participant organizations and individuals in the complex task are greatly appreciated.

This document should be viewed as a starting point for standardizing HEV testing. The task force members realize that both the technology and the methodology for testing HEVs are in their infancy. It is most likely that lessons learned in the process of testing HEVs and changes in HEV and testing technology in the coming years will require this document to be refined considerably from its present form.

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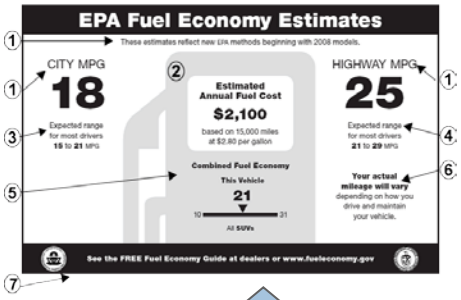


UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NHTSA

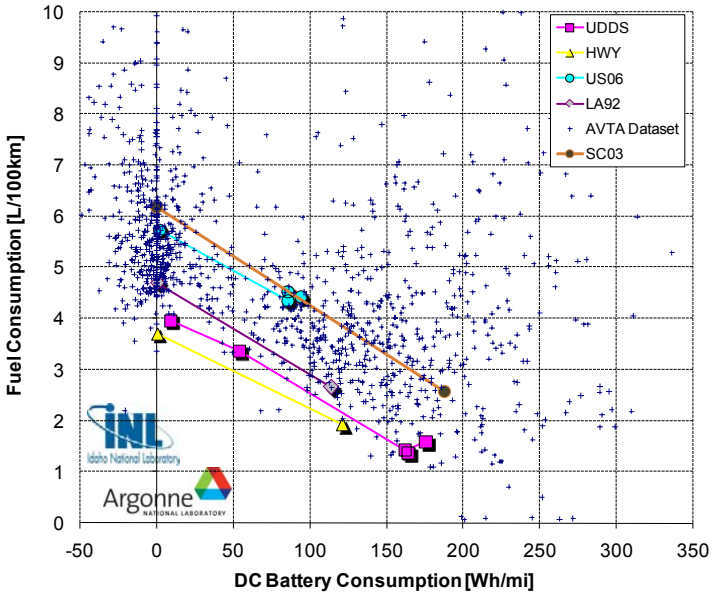
(DOT)
CAFE
calculation

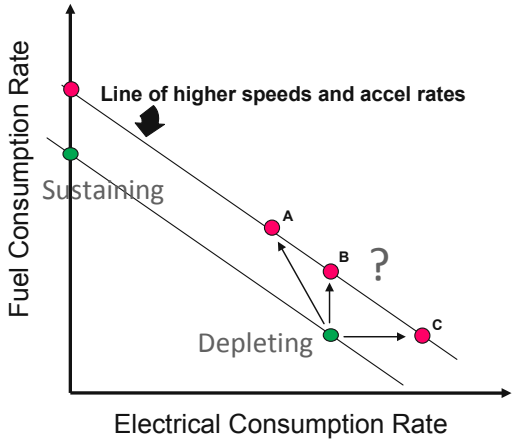
Considerable effort has gone into keeping CARB and ISO compatible with J1711

Collaboration With INL in Investigate How J1711 Test Results Compare to Fleet PHEV Data

Purpose: Put Goals of J1711 in Context

- Any vehicle is sensitive to in-use conditions lowering MPG
- PHEVs are sensitive to driving distances,
  - AVTA fleet has slight bias to shorter distances
- Hymotion conversion PHEV has specifically intense sensitivities to:
  - Higher speeds
  - Higher acceleration rates
- High energy use at high speeds actual lower electric consumption per unit distance (lowering MPG)





Collaborations: CARB, Environment Canada, and Chrysler Provided Test Data to Task Force

- CARB Provided early test data in support of new procedures
- Chrysler investigated charge-sustaining HEV in Cold UDDS to decide hybrid test requirements
- Environment Canada tested a Hymotion Prius to validate procedures for all cycles described in J1711 (UDDS, Highway, US06, SC03, Cold UDDS)

Future Work: Near Term and Longer Term

Near Term

- Journal article explaining J1711 rationale. A companion for any test engineer wanting to understand the background, limitations, and possible alternative options

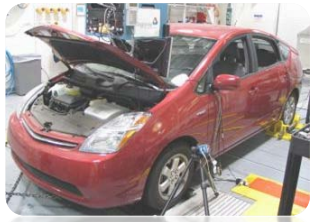
Longer Term

- SAE Procedures require re-ballot or rewrite every 5 years
- Early work on a J1711 “short-cut” could be revisited after more test experience is gained with early production PHEVs

Update Dyno Results and On-Road Experience

- Understanding In-Use PHEV performance:
  - DOE’s fundamental predictions of PHEV effectiveness requires precise understanding of in-use petroleum displacement
- Outreach activities on MPG or consumption of PHEVs

J1711 Summary


- Three years of development and supporting dynamometer test have culminated into a well-received procedure suitable for R&D, OEMs and potentially EPA
- Experts from USA, Europe and Japan provided many contributions and expert review
- Dozens of PHEV conversions and prototypes were tested at ANL supporting J1711
- Many final details required intense review and discussions in the last phase of J1711 development
- A comprehensive J2841 document is finalized with several UF curves available for characterizing PHEVs according to specific desired questions
- After several international pre-ballot reviews, a final document was sent to balloting in March 2010
- Superior institutional knowledge in testing electrified vehicles has become a key enabler to developing electric vehicle (J1634) standard