I Drive Cycle Equivalency During "A" to "B" Testing

EPA has proposed utilizing "A" to "B" testing in several areas of its proposed Medium- and Heavy-Duty ("MD/HD") Greenhouse Gas ("GHG") and Fuel Efficiency ("FE") Standards. For example, this testing protocol may be utilized in Part 1036, Subpart F for certain hybrid engines with PTO capability when the engine is coupled with a transmission; Part 1037; Subpart G for hybrid powertrains; Part 1037, Subpart F section 1037.525 for hybrid vehicles with PTO; and Subpart F section 1037.610 for hybrid vehicles and other advanced technologies.

In comments filed on January 31, 2011, Allison Transmission, Inc. ("ATI") outlined several issues concerning the drive cycle testing of MD/HD vehicles, including the ability of vehicles to follow a "trace," the proposed criteria for determining compliance, the proposed "A" to "B" testing of hybrid technologies and other issues.[1] ATI also submitted numerous questions on the proposed definitions of hybrid systems, testing systems for hybrids, the configuration of test vehicles, how "real world" comparison vehicles would be determined and other matters.[2]

A. Further Specification of "A" to "B" Testing

In light of these filed comments and ATI's current understanding of EPA's November 30, 2010 proposed regulations, EPA has the opportunity to clarify and provide further specification of "A" to "B" testing. Specifically, this could be done by:

1. Adopt the EPA criteria that the speed trace is followed within 2 mph within a 1 second window unless at maximum effort (reference "maximum effort" criteria), but add the following requirement:
    a. Total distance traveled has to be within 1% of theoretical.
2. Clarify that if condition specified in 1 a. is not met, the test must be re-run until the requirement is met. This would insure that both time and distance are equivalent (within 1%) for configuration A and B.
3. If 1 a. still cannot be met due to vehicle not being able to follow the trace, then the speed trace could be increased by a factor (for example: theoretical distance / actual distance) and the cycle would be rerun. This process could continue until item 1 a. (referenced to the original speed trace) is met.
4. Do not use data from tests that have a DPF regeneration event. If a DPF regeneration event occurs, re-run the test.
5. In the long term, comparison of the number of DPF regeneration cycles/1000 miles, for different technologies would capture the real world effect of different engine and transmission technologies on GHG emissions and gallons/1000 ton-miles.
6. Whenever vehicle speed is below the target speed, continue Wide Open Throttle ("WOT") acceleration until speed target is met, instead of starting dyne braking/torque control for the next deceleration event.
7. Update test procedures to account for new technologies as they are introduced, such as the need for warm up of DPF and SCR systems.

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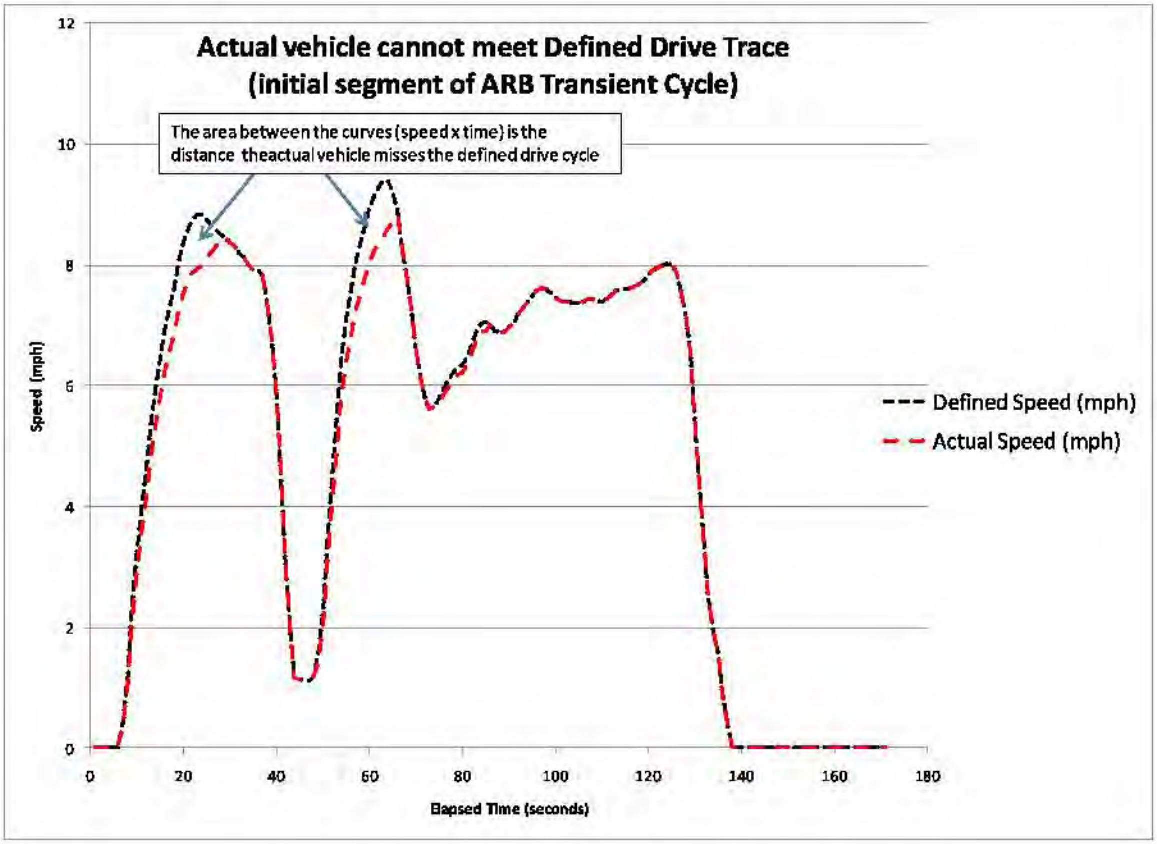
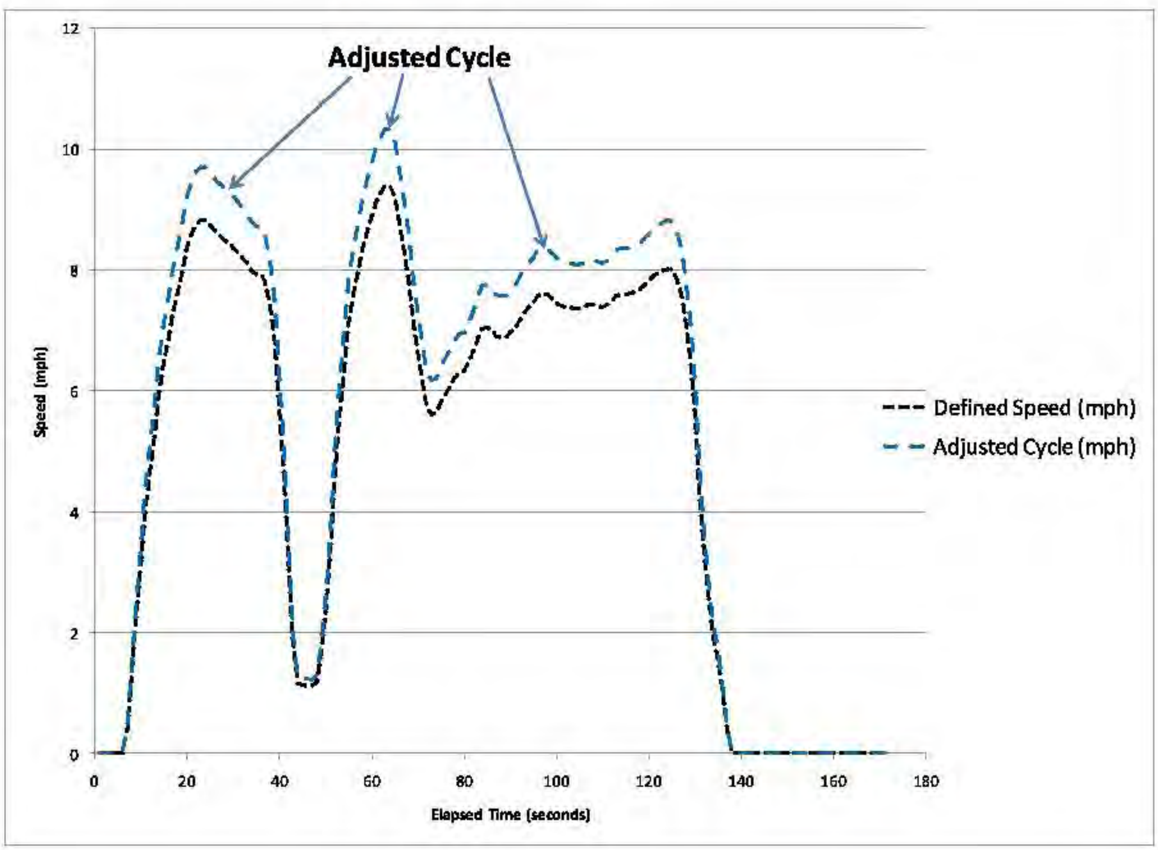
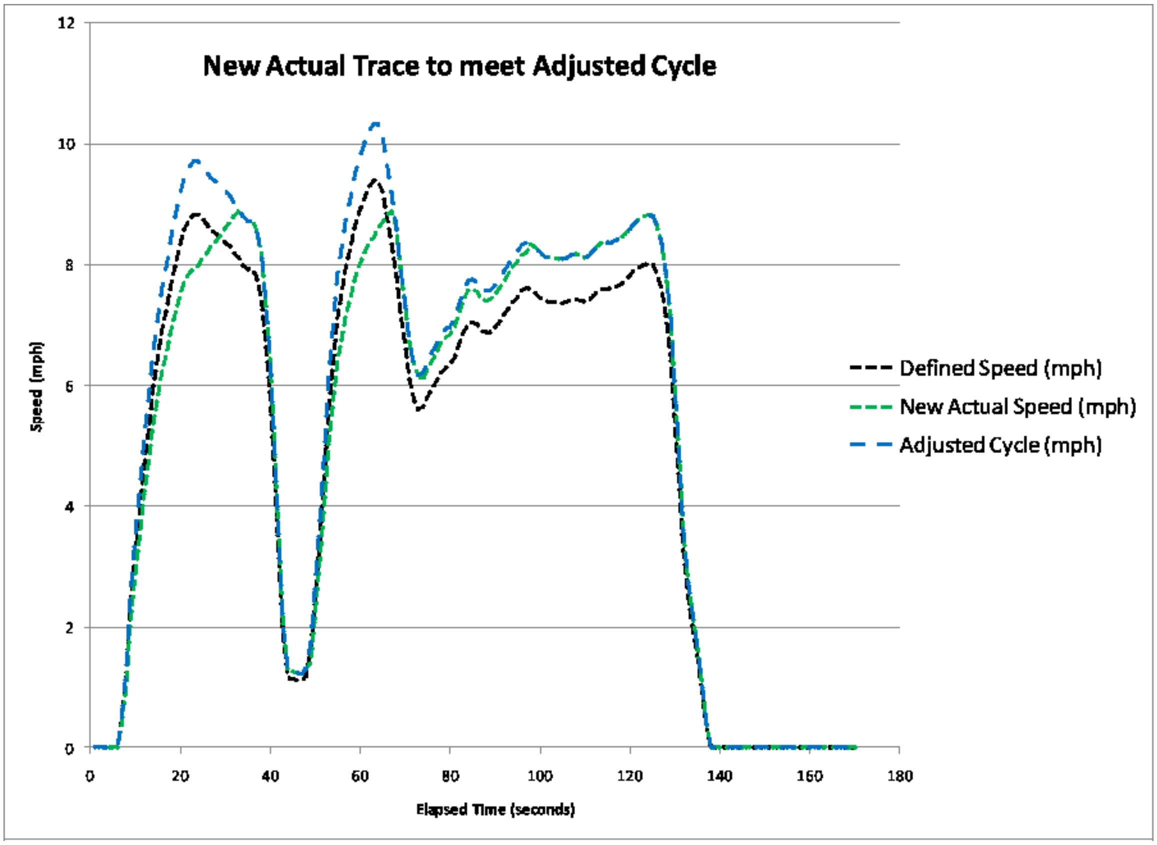
1 *See* e.g., Allison Comments, Sections XI and XII

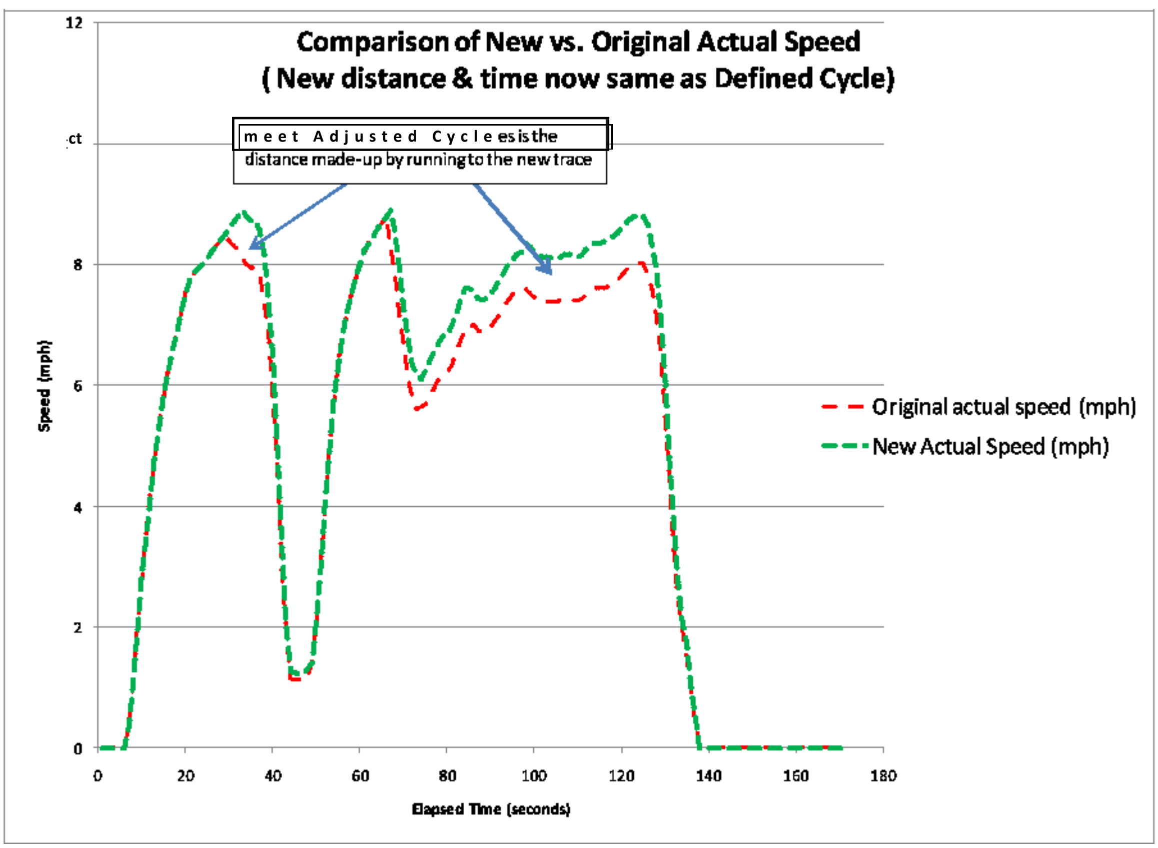
2 Id. at XII, B.

Example traces for which the above-described procedure number 3 could be implemented are shown below:






New Actual Trace to meet Adjusted Cycle
Speed (mph)
12
10
8
6
4
2
0
0
20
40
60
80
100
120
140
160
180
Elapsed Time (seconds)
Defined Speed (mph)
New Actual Speed (mph)
Adjusted Cycle (mph)


Comparison of New vs. Original Actual Speed
(New distance & time now same as Defined Cycle)
meet Adjusted Cycle esisthe
distance made-up by running to the new trace
Speed (mph)
12
ct
8
6
4
2
0
0
20
40
60
80
100
120
140
160
180
Elapsed Time (seconds)
Original actual speed (mph)
New Actual Speed (mph)

B. Alternative Procedure

Alternatively, the average speed ratio could be used to adjust the Raw Gallons/1000 ton-miles data as follows:

Adjusted Gallons/1000 ton-miles = Raw Gallons/1000 ton-miles X (average $speed_{reference}$/average $speed_{actual}$)

II. Definition of "A" and "B" Vehicles

"A" to "B" testing that is contemplated for the generation of credits (i.e., whether with respect to hybrid testing or otherwise) utilizes the concept of an "equivalent conventional vehicle" in order to assess relative GHG and FE "gains." Under the current regulatory concepts that are employed, the "equivalent conventional vehicle" would be defined with respect to utilizing the same footprint, intended service class, aerodynamic drag and other factors.

ATI comments and other comments received by EPA have reflected the importance of drivetrains and transmissions to affect GHG emissions and improve FE generally. Specifically with respect to "A" to "B" testing, however, it is important to incorporate such concepts within the definition of the "A" vehicle or the "equivalent conventional vehicle" to which assessment of improved GHG or FE performance is measured. In this respect, important variables which should be the same for the "A" vehicle and the "B" vehicle (except where such variables themselves are designed to directly produce improved GHG or FE performance) are:

- Transmission and Torque Converter
- Shift Calibration
- Engine
- Gross Vehicle Weight
- Axle Ratio

That is, EPA should hold the above vehicle components constant when "A" to "B" testing is performed to the greatest extent possible as determined by the advanced/innovative technology in order to assess any improvement in GHGs emitted or FE gained due solely to the use of hybrid systems or other advanced or innovative technologies. Failure to hold such components constant could increase the potential for gaming of "A" to "B" comparisons and the probability that improvements in GHGs or FE due to the hybrid systems or advanced or innovative technology will not be realized.

A conceptual chart as to how such components could be specified for different types of vehicles is represented below. Vehicles in a class would first be subdivided as to vocation. Following this classification, a standard configuration for transmission and drivetrain components, gross vehicle weight and engine type would be specified. Configurations would be determined on the basis of "normal and customary" practices in the industry for the type of vehicle involved.

Class 8 HD Vehicle

Vocation	Transmission & Torque Converter	Shift Calibration	Engines	Gross Vehicle Weight	Axle Ratio
Straight Truck (on-highway)			Cummins DDC Navistar Mack/Volvo		
Straight Truck (on / off-highway)					
Short Haul Tractor Trailer					
Line Haul Tractor Trailer					
City Bus					
Coach					

Notional - Data to be Inserted

III. Transient Drive Cycles/Weighting

ATI submitted comments with regard to GEM modeling and the steady state operating periods at 55 mph and 65 mph incorporated into the model.[3] We currently understand that the GEM model will include both steady state operations and transient cycle operation. As ATI also cited with respect to the compliance cycles for Class 7/8 Tractor Cabs,[4] the underlying assumptions and relative weighting of steady-state and transient operation of all MD/HD vehicles remains a crucial issue. Thus, any final decisions on the GEM should increase transient operation of vehicles, especially vocational vehicles, to better reflect real world vehicle utilization and traffic conditions. EPA has received multiple comments on this issue and thus has a sufficient basis on which to reweigh its proposed approaches to include a more accurate assessment of the transient operations of vocational and Class 7/8 tractor cabs, whether modeled or directly tested for compliance.

3 Id. at III. A. and B.
4 Id. at VI.

IV. Straight Line Acceleration

ATI previously provided comments on the straight line acceleration utilized in the GEM, noting the obvious difference between such assumed acceleration and the real world acceleration experienced by many different MD/HD vehicles.[5] While we would understand that in the GEM, straight line acceleration is not intended to be used for determining vehicle compliance with GHG/FE standards, questions remain with respect to the acceleration "curves" or drive cycle traces that may be utilized (either within the GEM or otherwise as part of compliance testing for the MD/HD GHG and FE program).

As noted below in Section VII, acceleration rates utilized in American Public Transit Association ("APTA") guidelines provide a publicly accepted method to measure acceleration broadly across different vehicle classes and types. That is, transit buses represent a ubiquitous commercial vehicle that is well-defined in the marketplace. Like other MD/HD vehicles, the relative fuel efficiency of such vehicles is a main factor affecting vehicle purchasing decisions. While MD/HD vehicles subject to regulation under EPA's proposed standards are obviously diverse, when selecting acceleration rates and drive cycle traces that will be utilized in compliance testing, the APTA transit bus cycle should be considered as providing a reasonably accurate and available methodology for assessing relative GHG emissions and FE associated with different MD/HD vehicles. Certainly, acceleration traces utilized in the APTA guidelines are far more accurate than "defaulting" to straight-line acceleration or utilizing acceleration rates that are unreasonably slow in the commercial marketplace.

V. Methods to insure the vehicle at least makes "best effort" if it cannot meet the drive cycle

Implicit in the concepts outlined above is the need to ensure that a vehicle being tested exerts the maximum effort in order meet the vehicle speed trace. We would understand that section 1066.330(c)(4) requires a vehicle to "operate at maximum available power" but that section 1066.330(e)(4)(iii) appears to not count insufficient acceleration as being outside of specified limits. As noted in previous comments, clarification of EPA's proposed regulations may be desirable on these matters. In specific:

1) Accelerator Pedal Position
  - A) The accelerator pedal can be monitored with a position sensor. For vehicles that use the J1939 CAN data link, monitoring the J1939 APP parameter being used by the engine or hybrid system is also acceptable.
  - B) Most engines use the APP parameter contained in the EEC2 message from one of the following source addresses: 17, 49, 33, or 00.
  - C) Most engines use one of the following APP parameters in the EEC2 message:
    - a) Accelerator Pedal Position 1 - SPN91
    - b) Accelerator Pedal Position 2 - SPN29
    - c) Remote Accelerator Pedal Position - SPN974

2) Kickdown switch activation (if equipped)
3) Performance/Economy Mode Selection (if equipped)
4) Gear selected provides maximum performance. This would include requiring the driver to override automatic gear selection if that would improve performance to the speed trace.

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5 Id. at III. A.

5) Other driver selectable methods to increase vehicle acceleration and speed capability, such as selectable input to vehicle acceleration rate management control (if equipped).
6) Monitor the J1939 TSC1 message for torque or speed limits (or control) from external devices for all tests.
7) Require 100% APP, kickdown engaged, performance mode selected, etc. whenever the vehicle (or powerpack, or engine) cannot meet the speed trace.

VI. Pre-transmission "A" to "B" testing for advanced technologies, such as hybrids

EPA's proposed metric and testing protocols are based on the concept of measuring the work performed by vehicles. To further EPA's objective, there is a need to ensure that interactions between the vehicle, engine, and hybrid system components are accounted for – in a similar fashion – in both pre- and post-transmission test methods. Pre-transmission "A" to "B" testing for hybrids should not get an unrealistic advantage compared to hybrids that use post-transmission or vehicle testing. This could be ensured by requiring that:

- Energy Storage System ("ESS") usage be equivalent to usage in a real world hybrid system. For this, the hybrid system and ESS production controls would need to be used for the testing. Otherwise, the ESS could be used more than in a production vehicle which would skew the results.
- The accessory configuration for the vehicle must be replicated for the pre-transmission and post-transmission test cell test setups. It should at least simulate a real world vehicle. This is important since accessory loads will reduce the amount of regenerative energy captured.
- The amount of regenerative braking captured for the pre-transmission test cycle must not be more than the post-transmission test or vehicle test would provide.

VII. "A" to "B" test gaming by changing engine accessory loads, including PTO operation

In general, "A" to "B" tests should include realistic accessory loads regardless if they consist of a pre-transmission test, post-transmission test, or complete vehicle test. Accessory loads would include a 12/24 volt alternator and the loads that it drives on the vehicle, air or hydraulic service brake power booster, power steering, engine radiator fan, engine water pump, and air conditioning compressor.

Accessory loads should also be the same for both A and B tests. If both A and B configurations use accessories that are mechanically driven by the engine, the parasitic torque vs. engine speed should be the same for both A and B tests.

If electrically driven accessories are used for the B configuration, the output of the accessory should be the same for both A and B tests. For example:

- The 12/24 volt electrical system loading should be set at a realistic level (or duty cycle) and be the same regardless of whether an alternator or a DC-DC converter is used to service the 12/24 volt load.
- Engine radiator fan output shall remain adequate to cool the engine for both engine driven and electrically driven fans. Likewise for electrically driven engine water pumps.

- Power steering hydraulic output power vs. time duty cycle shall be realistic, and the same for both engine driven and electrically driven power steering systems.
- Air conditioning output should remain adequate to control cabin temperature under standard conditions for both engine driven and electrically driven compressors.

Additional electrical load needed to drive the electrically driven accessories should be included in the "A" to "B" tests. This could be on the 12/24 volt system or the high voltage system, depending on the accessory. Otherwise, EPA should only use the Refuse part of the PTO cycle for the duty cycle weighting for Refuse trucks and only use the Utility part of the PTO cycle for the duty cycle weighting for Utility trucks. The proposed Utility and Refuse PTO cycles should also be compared with the broad range of duty cycles in actual use to see if adjustments to the cycles are needed.

VIII. Minimum performance criteria for "A" to "B" tests.

ATI's filed comments cited the advantages of hybrid technologies and the need to accurately recognize these advantages within the regulatory system. Items that would accomplish these ends would include:

1) Allow freedom for hybrid systems to de-rate the engine or <u>downsize to a smaller engine family.</u>
2) Allow changes in tire size and axle ratio to optimize the hybrid system compared to a conventional system.
3) Require both vehicles to meet minimum commercially acceptable performance criteria for startability and acceleration, as defined below. "Commercially acceptable" would generally constitute what is reasonable and normal in the existing market.
4) Use APTA bus acceleration requirement for all vehicles (vocational, day cabs and sleeper cabs).[6]

uid	
era	eve
4a	

10

eed

6 *See* "Standard Bus Procurement Guidelines RFP," American Public Transportation Association, October, 2010. Reference Section TS 7.3 Acceleration, pages 76 and 77.

cle weight = GVWR

5) For vehicles incorporating automatic transmissions, utilize the minimum startability requirements[7] represented on the chart below:

Application	Min Startability % Grade
Sleeper Cab	12
Day Cab	12
Transit	16
P&D / Delivery	15
Refuse	15
Utility / Boom	15

6) For manual transmissions and automated manual transmissions, startability should be calculated in the lowest (automatic) starting gear with the engine at clutch engagement torque (i.e., in lug-up condition at a maximum of 800 rpm).

IX. Accessory Load Values

As indicated previously in Section III above, it is important to realistically define accessory loads given their effect on testing results. The accessory loads shown below are the typical parasitic losses used by the ATI's iSCAAN vehicle application and performance evaluation tool for all vehicle classes within each application category. More precise values may also be entered into iSCAAN to better define the losses associated with an individual vehicle's unique configuration.

Min Sttability
on d

For example:

Standard Accessory Power/Percent Typical Value

ery 1

Urban City Transit - 1

om**Class 8**

Fan	Percent of Peak Power	10
Alt/Generator	Percent of Peak Power	5
Air Compressor	Percent of Peak Power	4
Steer Pump	Percent of Peak Power	1
Air conditioning	Percent of Peak Power	7

7 Minimum Startability by Application is defined within Allison Transmission Technical Document TD 180-3 "Vocational Performance Guidelines for Allison Transmissions."

P&D Delivery - Class 5,6, and 7

Fan	Percent of Peak Power	6.5
Alt/Generator	Percent of Peak Power	0.5
Air Compressor	Percent of Peak Power	0.5
Steer Pump	Percent of Peak Power	0.5
Air conditioning	Percent of Peak Power	1

Day Cab - Class 7, 8

Fan	Percent of Peak Power	6.5
Alt/Generator	Percent of Peak Power	0.5
Air Compressor	Percent of Peak Power	0.5
Steer Pump	Percent of Peak Power	0.5
Air conditioning	Percent of Peak Power	1

Refuse Packer - Class 7, 8

Fan	Percent of Peak Power	6.5
Alt/Generator	Percent of Peak Power	0.5
Air Compressor	Percent of Peak Power	0.5
Steer Pump	Percent of Peak Power	0.5
Air conditioning	Percent of Peak Power	1

Line Haul - Class 8

Fan	Percent of Peak Power	6.5
Alt/Generator	Percent of Peak Power	0.5
Air Compressor	Percent of Peak Power	0.5
Steer Pump	Percent of Peak Power	0.5
Air conditioning	Percent of Peak Power	1

Utility Truck w/Boom - Class 6, 7

Fan	Percent of Peak Power	6.5
Alt/Generator	Percent of Peak Power	0.5
Air Compressor	Percent of Peak Power	0.5
Steer Pump	Percent of Peak Power	0.5
Air conditioning	Percent of Peak Power	1

X. Advanced/Innovative Technology Credits

EPA has received many comments supporting advanced technology credits and innovative technology credits. Both credit programs could offer benefits. EPA has proposed only general criteria with respect to the methodology for obtaining innovative technology credits, but the Agency should be aware that:

- Smaller engines can be used with an automatic transmission to achieve the same performance as an AMT or manual transmission, enabling significant reductions in GHGs emitted from a vehicle and improved FE. In this regard, the use of the term "technologies that were not in common use before 2010" might be interpreted to exclude technologies that may have been in existence in considerable numbers, but had not been utilized in new or widespread combinations or configurations. It would appear that EPA's intention in this matter would *not* be to exclude such approaches to obtaining GHG reductions and FE gains where the actual deployment of the technology did not occur, or did not commonly occur in the specific configuration or combination for which credit is sought. Instead, it would be reasonable to interpret the "common use" criteria as "common use, or in common use in a particular combination or configuration."

- Alternate fuel powertrains, specifically those utilizing CNG engines, could lower GHG emissions and improve FE. Such powertrains should either meet the applicable definitions to be eligible for credits, or be made eligible for credits.