Dec 9, 2013

Clerk of the Board, Air Resources Board

1001 I Street, Sacramento, CA 95814

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**Lightning Hybrids written comments concerning *Proposed Amendments to the California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric and Other Hybrid Vehicles, in the Urban Bus and Heavy-Duty Vehicle Classes.***

**Introduction:**

Lightning Hybrids currently produces a hydraulic hybrid drive system for use on new vehicles in the Heavy Duty class, specifically Transit Buses and Delivery Trucks from 14,000 to 30,000 GVWR. Vehicles based on the Ford E450 Commercial Cutaway and Ford F59 Stripped Chassis (Stepvan) are operational in fleets outside of California, and are producing marked improvements in Fuel Economy as well as reducing emissions. The Lightning Hybrids design features a post-transmission, parallel architecture. It uses ARB certified engines with no modifications to the engine or exhaust components. The system captures regenerative brake energy in the form of hydraulic pressure and then supplies it for propulsion to supplement or replace motive power provided by the certified Internal Combustion Engine (ICE). It is Lightning Hybrid's desire to meet the demand of its California customers for this technology. Hydraulic Hybrid Vehicles (HHVs) are fielded in substantial quantities elsewhere in the nation, and are a demonstrated and relevant technology. Their inclusion in the proposed amended procedure is critical to the growth of the industry. While the proposed amendments address hydraulic hybrids in general, they do not provide adequate specifics to enable the manufacturers of these vehicles to certify their products by Executive Order. Written comments are included below. Oral presentation of these comments as well as additional input and amplification will be provided by Lightning Hybrids at the Public Hearing on Dec 12, 2013.

**Lightning Hybrids, LLC Comments:**

**Comment 1**

Sect C, paragraph 12, Page 12

*" 12. Hydraulic, Turbine, Flywheel, or Fuel Cell Hybrid Vehicles. The certification application will be considered by the Executive Officer on a case-by-case basis. Upon approval of the Executive Officer, the stated certification requirements on section C shall be followed for these hybrid vehicles, as applicable."*

Sect D, introduction, Page 12

*"The test procedure for determining compliance with standards applicable to the hydraulic, turbine, flywheel, or fuel cell used as the motive power in a hybrid electric vehicle shall be determined by the Executive Officer on a case-by-case basis."*

These paragraphs give inadequate guidance to manufacturers of Hydraulic Hybrid Vehicles (HHVs), and give unreasonable discretionary power to the Executive Officer of the ARB concerning the implementation of this technology in California.

A hydraulic accumulator is a RESS as defined in this document. An HHV can be certified by the ARB using the exact procedure outlined for HEVs. The only additional information required is an equation to define the hydraulic State of Charge (SOC) and the Net Energy Change (NEC), as well as some associated definitions. These are simple calculations based on change in accumulator pressure. Following calculation of NEC, certification compliance is determined just as with HEVs. The intent of these calculations is to determine whether a charge depleting operation is in place, and this applies equally to HHVs. The equations are listed below:

The SOC at any time can be determined by comparing the stored energy at any given time to the maximum stored energy of the system by measuring the pressure in the accumulator at any given time. n is the Heat Capacity Ratio. At any given time, the system may lose heat with minimal change in temperature making the isothermal process an acceptable assumption for this process.

$$SOC = \frac{\left(P^{\frac{n-1}{n}} - P_0^{\frac{n-1}{n}}\right)}{\left(P_f^{\frac{n-1}{n}} - P_0^{\frac{n-1}{n}}\right)}$$

Where :

- $P_f$ = Maximum Pressure Accumulator Pressure
- $P_0$ = Accumulator Pre-charge Pressure
- P = Pressure at time of measure
- n = Heat Capacity Ratio (1.8 for high pressure nitrogen)

The NEC Calculation determines the Net Energy Change of the system in a drive cycle by using the pre-charge volume and pressure, and the initial and final pressures measured at the start and end of the test respectively.

NEC = $\frac{V_o {P_0}^{1/n}}{n-1}\left(P_f^{\frac{n-1}{n}} - P_i^{\frac{n-1}{n}}\right)$

Where :

- $V_0$ = Accumulator Precharge Volume
- $P_0$ = Accumulator Precharge Pressure
- $P_i$ = Initial Pressure of the Accumulator
- $P_f$ = Final Pressure of the Accumulator
- n = Heat Capacity Ratio (1.1 for isothermal process)

**Comment 2**

Throughout this document (including the title), the document uses the term Hybrid Electric Vehicle (HEV) to describe hybrid vehicles generically. The term Hybrid Vehicle should be used to describe the general class, and the term Hybrid Electric Vehicle should only be used to describe specific vehicles whose motive power and storage systems are in fact, electric.

**Comment 3**

This document is described and titled as Interim. It has been in place for 11 years and will remain in place following this amendment. This is not an interim measure.

**Comment 4**

This procedure is also described as optional for the manufacturer of Heavy Duty Hybrid Vehicles yet it offers no alternative procedure. What is the other option for certification? This appears to be a mandatory procedure, and fails to address the actual cost of ARB certification and testing to the manufacturer.

Lightning Hybrids, LLC appreciates the opportunity to be involved in the amendment process for these test procedures. As recognized innovators and experts in the field of Hydraulic Hybrid Vehicles, we are pleased to provide additional information to the ARB concerning the specifics of the technology and how it can be implemented to reduce emissions and improve vehicle fuel economy in California. Lightning Hybrids' technology targets some of the poorest performing vehicles in these areas and promises a substantial impact. We look forward to collaborating on Dec 12, and into the future.

Regards, Brian Johnston, Lead Systems Engineer

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