THE DEPARTMENT OF ENERGY'S HIGH-POWER ENERGY STORAGE PROGRAMS

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INTRODUCTION

The goal of the Office of Advanced Automotive Technologies (OAAT) is to develop and validate vehicle system technologies that will facilitate the production of competitive, consumer acceptable automobiles having a fuel economy of up to 100 mpg while meeting projected statutory emission and safety standards and having the capability to use domestically produced alternative fuels. Specific system level objectives call for validating technologies that can achieve 50, 80, and 100 mpg by 1998, 2001, and 2011, respectively, in a mid-size, six passenger vehicle. An aggressive hybrid propulsion system development program is underway in partnership with key government and industry partners.

A key technical barrier to achieving the vehicle systems program objectives is the lack of an adequate high-power energy storage device which is needed to level the dynamic load profiles for the powertrain, recover the energy from the regenerative braking systems, and store unused engine output during braking and idle periods. Based on the hybrid vehicle requirements, detailed technical targets at the subsystems level have been developed for high-power energy storage supporting the 80-mpg vehicle objective of the PNGV. These technical targets are shown in Table 1. Two sets of parallel targets have been developed for the fast-response engine and the slow-response engine. These targets differ considerably from those for the electric vehicle batteries being developed under the DOE-U.S. Advanced Battery Consortium (USABC) cooperative agreement.

The leading candidate technologies with potential to meet program requirements are high-power batteries, ultracapacitors, and flywheels. At present, candidate high-power battery technologies cannot simultaneously satisfy the power density, energy density, and cycle life requirements. Advanced ultracapacitor technologies may provide adequate power to meet the goals, but their projected energy densities are not sufficient for them to be used in all hybrid configurations. A combined battery/ultracapacitor subsystem may offer an approach to meeting the goals. Combining the battery and ultracapacitor into an integrated subsystem, however, presents new challenges in electric power sharing, controls, and physical packaging as well as meeting cost goals. Overall, the primary development challenges for high-power storage are to achieve high power-to-energy ratio and long cycle life while meeting ambitious efficiency, weight, volume, and affordability goals.

In response to the above need, OAAT is devoting considerable resources to developing high power storage technologies. A distinct High-Power Energy Storage Program was initiated in FY 1995 to continue and expand ongoing projects in ultracapacitors and initiate a broad range of new activities

in high-power batteries and flywheels. Budget appropriations for the program have increased from $1.9 million in FY 1995 to $8.1 million in FY 1996, with a budget request of $17 million for FY 1997. In this effort, DOE is supporting domestic auto companies, battery manufacturers, and other suppliers as well as the national laboratories and universities. Recognizing the enormous market potential for advanced energy storage devices in vehicle and consumer/industrial applications, the industrial partners are also investing large internal resources in the R&D program. The remainder of this paper will summarize DOE program objectives, FY 1996 accomplishments, and plans for FY 1997 in the three focus areas of high-power batteries, ultracapacitors, and flywheels.

TABLE 1. Energy Storage Requirements For Hybrid Vehicles

Characteristics	Units	Fast-Response Engine		Slow-Response Engine	
		Minimum	Desired	Minimum	Desired
Pulse Discharge Power (constant for 18 seconds)	kW	25	40	65	80
Peak Regenerative Pulse Power (trapezoidal pulse for 10 seconds for the specified pulse energy)	kW	30 (for 50-Wh pulse)	60 to 110 (for 150-Wh pulse)	70 (for 150-Wh pulse)	150 (for 150-Wh pulse)
Total Available Energy (discharge plus regenerative)	kWh	0.3	0.5 to 0.75	3	3 to 8
Minimum Round-trip Efficiency on FUDS/HWFET cycle	%	90	90	95	95
Cycle Life, for Specified SOC Increments:		200K for 25 Wh 50K for 100 Wh	300K for 35 Wh 100K for 100 Wh	120K for 100 Wh 20K for 600 Wh	300K for 200 Wh 100K for 600 Wh
Calendar Life	year	10	10	10	10
Maximum Weight (plus marginal increase/kWh for E>3 kWh)	kg	40	35	65 (+10kg/kWh)	50 (+10kg/kWh)
Maximum Volume (plus marginal increase/kWh for E>3 kWh)	l	32	25	40 (+8l/kWh)	40 (+8l/kWh)
Maximum Package Height	mm	150	150	150	150
Production Cost, at 100,000 Units Per Year (plus marginal increase/kWh for E>3 kWh)	$	300	200	500 (+$62.50/kWh)	500 (+$62.50/kWh)
Operating Voltage Limits:	vdc	300 min 400 max	300 min 400 max	300 min 400 max	300 min 400 max
Maximum Allowable Self-discharge Rate	Wh/ day	50	50	50	50
Temperature Range: Equipment Operation Equipment Survival	°C	-40 to +52 -46 to +66	-40 to +52 -46 to +66	-40 to +52 -46 to +66	-40 to +52 -46 to +66