Kinetic Art & Technology
BARP Proof-of-Concept Vehicle
Demonstration & Test Report

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Purpose

The purpose of this document is to summarize the demonstration and testing of the Zero Kar proprietary Battery Alternating Recharge Process (BARP) Proof-of-concept (POC) vehicle witnessed by Kinetic Art & Technology personnel on June 17, 2010.

In addition, probable conclusions regarding the viability of the BARP process as part of a vehicle propulsion system are provided.

Overview of Zero Kar Project

The BARP process was conceived and developed by Michael Hargett as described in Patent Application 20100001686 and subsequent patent applications. Mr. Hargett formed a team, which included private investors and company owners able to provide valuable services, to build a proof-of-concept vehicle to demonstrate that the BARP process could power an electric vehicle with no need to plug the vehicle into utility electricity to charge it.

Overview of BARP Process

The Battery Alternating Recharge Process is relatively simple. As employed in the POC vehicle, it is an added component to a series electric hybrid vehicle. Rather than having a single battery pack, as would be employed in a typical conventional series hybrid, the BARP process employs two battery packs. One battery pack drives the fully electric traction drive while the alternate battery pack is being charged. Once the drive battery bank is depleted, the fully charged battery bank is switched to become the drive bank and the depleted battery bank is then charged. This process continues to cycle.

While any source of electric energy could be used for the BARP process, the POC vehicle employs a conventional Kohler gasoline engine, a 30KW class SEMA 3-phase generator and a custom 3-phase bridge rectifier to charge the batteries. As long as the charge time for the battery packs is less than the drive time of the battery packs, a vehicle employing the BARP process should be able to continue operation, while alternating charging battery banks, until the fuel for the engine and the energy in the battery banks has been consumed.

Description of POC Vehicle

Note that operation of the POC vehicle was first witnessed by Tharon Hall and Keith Seymour of Kinetic Art & Technology at a demonstration at NASA Glenn Research Center on June 10, 2010. The two gentlemen drove the vehicle at that time. However, the goal at the time was simply to experience the vehicle, not to verify the BARP process.

Note also that the detailed description of the POC vehicle components is largely taken from discussions with the Zero Kar team and the document "Technical Description of the *Zero Car*, Proof of Concept Vehicle for the *Battery Alternating Recharging Process*" dated June 7, 2010 and authored by Timothy A. Jenkins, PhD, Department of Physics, University of Oregon. While only limited effort was made to confirm the precise details of Dr. Jenkins' description of the vehicle, his description matches inspection of the system by Kinetic Art & Technology (KAT) personnel.

The POC vehicle is a one-of-a-kind vehicle built specifically to demonstrate the BARP process. It was converted from a three-wheeled ZAP! Xebra sedan. To make room for the POC hardware, the rear seats were removed, leaving the POC vehicle a two passenger vehicle. The entire drivetrain was essentially replaced. For promotional purposes, the vehicle is painted glow-in-the-dark green.

Figure 1- BARP POC Vehicle

The electric traction drive of the original Xebra was removed and replaced by an Azure Dynamics 24 HP (18 kW) traction drive and transaxle module. This system allows the vehicle to reach highways speeds. Speeds in excess of 70 MPH have been achieved.

Generator System

The generator portion of the POC vehicle consists of a Kohler Command Pro CH 1000 gasoline engine with a five gallon tank. It drives a 338-4-34.3 SEMA 3-phase generator through a pulley coupled to a magnetic clutch. The pulley steps the speed up for the SEMA generator, and the clutch removes the inertia of the generator while starting the Kohler engine. The clutch is engaged once the engine is running. After clutch engagement, the generator is then ramped up to, or near, its 5,000 RPM rated speed, providing enough voltage to charge a battery bank.

Figure 2- POC Vehicle Generator System

The fuel tank for the Kohler engine is mounted above it and is gravity fed to the engine.

Batteries

The POC vehicle utilizes two lithium iron phosphate battery packs with a nominal fully charged capacity of 28 MJ. However, as these types of batteries can only be rapidly charged to 80% of their capacity, the practical capacity utilizing the BARP process is 22 MJ. The battery packs are made up of M size cells purchased from AA Portable Power Corporation. The battery management system was manufactured by Genasum Advanced Energy Systems.

Figure 3- Lithium Iron Phosphate Cells

The test results experienced by Dr. Jenkins in his testing were done prior to an attempt to improve balancing by using automotive chargers to charge the batteries in attempt to improve the balance of the batteries prior to the demonstration at NASA Glenn Research Center. The Zero Kar team was following the advice of a technician at *batteryspace.com*. This proved to be a setback for the vehicle, as the effort had exactly the opposite effect. The batteries became very unbalanced and the battery banks demonstrated much lower charging capacity at NASA Glenn Research Center and at KAT than they had for Dr. Jenkins' testing. This fact has limited the range of the car. Further charge and discharge cycling may improve the balancing of the batteries and improve the driving distance. In addition, improved battery technologies will also extend the range of the vehicle.

Figure 4- POC Vehicle Battery Bank #1

Battery Bank #1, as shown in Figure 4, is located down the centerline of the vehicle between the driver and passenger seats. Battery Bank #2 lies perpendicular to the vehicle centerline and lies behind the two seats.

Manual BARP Process

The Zero Kar team lacks the funding necessary to automate the BARP process. In addition, the POC vehicle's traction drive system does not handle switching battery banks while driving. Therefore, in order to switch battery banks, the vehicle must be stopped. The recharge process is then initiated by starting the gasoline engine, engaging the clutch, then throttling up the generator to create enough voltage to charge the batteries. The vehicle can then be driven on the previously charged battery bank, with or without charging the other battery bank. This process is something that could be automated without considerable difficulty and requires no apparent technological advances. With sufficient funding, a fully automated BARP process should be readily achievable.

Test Procedure

The charging times were recorded for each charging sequence. A magnetic clutch engages the generator two seconds after a switch is thrown. The transition when the clutch engages is very audible as the engine encounters the inertia of the generator. The generator is then immediately throttled up to begin the charging sequence. When the battery bank is full, there is a very audible change in the operation of the motor as the battery management system opens the charging relay, thus releasing the electrical load from the generator, giving the indication that the charge cycle is complete.

During the initial runs, the charging of a battery bank was done while stationary to make it easier to record the charge time and the drive time. Later, charging was done while driving on the previously charged battery bank to better simulate the BARP process as it was intended. As the odometer in the test vehicle was known to be inaccurate, a chase vehicle was utilized to record mileage for each drive cycle. The traction drive simply shuts off and beeping is heard when the batteries are low, making the end of the drive cycle readily apparent.

Test drives 1 through 3 were performed in the suburban/rural driving conditions in and around Greenville, Indiana. Captured drive times do include some periods in which the vehicle was at rest waiting on traffic. Drives 4 through 6 were performed while driving on US150 between Greenville and Palmyra, Indiana. These later drives were intended to better simulate the eventual usage of the BARP process by charging the depleted bank while running on the previously charged bank.

Figure 5- Rear of POC Vehicle

Test Results

The results of the POC vehicle demonstration are summarized in Table 1. For Tests Drives 1 through 3, even accounting for stops necessary in the suburban/rural driving environment around Greenville, Indiana, it was clearly obvious that each charge cycle was much shorter than the amount of time the vehicle could be driven on a battery pack.

Table 1- POC Vehicle Test Results

Test Drive	Drive Bank	Approx. Drive Time	Drive Distance	Charging Bank	Approx. Charging Time
1	1	10 min 30 sec	4.4 miles		
				1	4 min 19 sec
2	2	17 min	7.5 miles		
				2	5 min 14 sec
3	1	15 min 21 sec	6.3 miles		
4	2		6.9 miles	1	4 min 35 sec
5	1		5.3 miles	2	5 min 46 sec
6	2			1	5 min

During Test Drives 4 to 6, the goal was to fully charge the depleted bank while running on the previously charged bank. Even at highway speeds of up to 60 MPH, this was handled easily. Note that these later tests are worse case, as the higher vehicle drag at highway speeds depletes the batteries more rapidly and continuously, as compared to the driving conditions in and around Greenville.

Conclusions

The POC vehicle has various issues not uncommon to such efforts. Specifically, there are issues with clutch engagement and battery capacity. In addition, the BARP process is not automated. However, none of these are issues that could not be resolved with time and adequate resources.

Give that the generator system in the POC vehicle can easily charge a battery bank well within the time it takes to discharge the other battery bank, there is no reason that with improvements and an automated charging process, the POC vehicle would not be capable of operating entirely free from utility electric power. Rather, the vehicle would derive all its energy from the fuel consumed by the gasoline engine.

Should a series hybrid electric vehicle, optimized for and with the BARP process, be demonstrated, there could be an efficiency advantage by operating an internal combustion engine driven generator (or other electric energy source) at its maximum efficiency when charging a battery bank, and allowing the battery pack to provide energy to the traction drive on an as-needed basis.