

CASE STUDY

Chevy Volt Uses LDS Vibration Test System for Electric Vehicle Battery Durability Tests

USA
Automotive
LDS Shakers

Hybrid power technology development is ramping up globally in today's ultra competitive automotive industry – and these technologies of the future demand vibration test solutions that can efficiently perform accelerated lifetime tests even on large and fully operational assemblies.

General Motors' 3000 m² battery test laboratory at The Alternate Energy Center, Warren Technical Center, Warren, Michigan, USA tests battery cells and packs for the Chevrolet Volt electric vehicle. An LDS Vibration Test System is used for electric vehicle pre-production qualification and functional test of a complete T-shaped battery assembly designed to be mounted underneath the car. The weight of the battery unit can exceed 190 kg.



General Motors



General Motors, one of the world's largest automakers, traces its roots back to 1908. With its global headquarters in Detroit, GM employs 204,000 people in every major region of the world and does business in some 140 countries. GM and its strategic partners produce cars and trucks in 34 countries, and sell and service these vehicles through the following brands – Buick, Cadillac, Chevrolet, GMC, GM Daewoo, Holden, Opel, Vauxhall and Wuling. GM's largest national market is the United States, followed by China, Brazil, Germany, the United Kingdom, Canada, and Italy.

General Motors has long experience with electric vehicles starting with the electric concept car Impact which was introduced at the 1990 Los Angeles Auto Show. By 1996, the design had evolved into GM's EV1. The EV1, produced and leased by the General Motors Corporation from 1996 to 1999, was the first mass-produced and purpose-designed electric vehicle of the modern era from a major automaker, and the first GM car designed to be an electric vehicle from the outset.

The Chevrolet Volt – Impressive Performance

Fig. 1

The new Volt MPV5 crossover version of the Chevrolet Volt was introduced at the Auto China Motor Show in April 2010. It can manage 32 miles (51.5 km) on pure electric propulsion. When the battery is depleted, a 1.4 litre engine generator kicks in to sustain the battery charge and provide up to 482 km of electric propulsion



The Chevrolet Volt is an electrical vehicle. Hailed as the spiritual and technological successor to the EV1, it will be launched in November 2010 as a 2011 model and has a "Voltec" extended range propulsion system.

Anthony (Tony) Cullen has worked for GM for 20 years, mainly for the Milford Proving Ground Group. He has been involved with the GM-Volt battery vibration test lab since it came online in the second quarter of last year. Today, he is Lead Test Engineer for the vibration room in the laboratory. The battery test lab has seven Lead Test Engineers, four of whom are dedicated to battery testing, and one each for cell, vibration

and abuse testing. GM has announced that it will expand the battery test lab in Warren to almost double the size and add capacity during the coming months. The current, state-of-the art lab began operations in January 2009 and is used by more than 1000 engineers to test cells, modules, and entire packs.

Tony says, "The development of the Volt is unique with its on-board generator. It uses kinetic energy to charge the lithium-ion batteries and a standard Volt in urban driving conditions will do 40 miles [64 km] on a full battery charge". He continues, "Once the energy in the battery reaches a specific level, the on-board 1.4 litre gasoline engine takes over and powers a generator to supplement the battery. The engine and generator now supply power for the vehicle, and everything is automatically controlled by sophisticated on-board computer systems".

The Volt production line, located at the Cadillac plant in Detroit is now being finalised and GM also recently announced a \$43 million investment in Brownstown Township, Michigan to manufacture the required lithium-ion battery packs. GM will also become the first major US automaker to produce its own electric motors, with a \$246 million facility in Baltimore, Maryland planned for 2013.

The Battery

Fig. 2

The T-shaped battery pack can weigh up to 190 kg

As the electrification of cars continues to gain momentum, GM reinforces its recognition of the importance of the most expensive component in any electric vehicle – the batteries – with its plans for the Brownstown Township facility. However, until then the Volt's lithium-ion battery cells are supplied by LG Chem.

The T-shaped battery packs weigh over 400 lbs, are water-cooled and have a capacity of about 400 amps at 400 volts. In the laboratory they are tested under extreme conditions – high and low temperatures, extremes of humidity, and different road conditions – to determine whether they will last for the life of the car.



The LDS Vibration Test System

Tony explains his team's tasks, "The main purpose of the vibration lab is to test the battery's durability by simulating its lifecycle. The targeted lifetime of the battery is ten years. In addition to vibration, various other tests such as thermal and mechanical fatigue are carried out. The random vibration test lasts for 48 hours, that is, 48 hours of random vibration input and shock pulses. The data to power the shaker is acquired from a Volt on the GM proving ground. They test the battery in the x, y and z axes – one at a time – and each axis test takes 16 hours."

Vibration testing also takes place in a climatic chamber where temperature and humidity are strictly and closely controlled. The environment in the climatic chamber can range from -30°C to $+78^{\circ}\text{C}$, and each 16-hour axis test is carried out under controlled temperature and humidity conditions.

To meet GM's testing demands, the system used had to be high-performing and versatile and easily adaptable to several test demands on large heavy payloads in multiple axes. The LDS Vibration Test System delivered perfectly fulfils GM's requirements for a heavy-duty system, able to perform accelerated durability test simulating the lifetime of the car. This includes several days of continuous testing at very high vibration levels and extreme temperatures.



Battery Pre-production Qualification and Functional Test

The system is used for electric vehicle pre-production qualification and functional test of a complete T-shaped battery assembly designed to be mounted underneath the car.

The test is performed continuously over several days in a climatic chamber temperature cycled over a very large temperature range. One requirement for the system was that it should be capable of delivering a continuous vibration level of several Gs with a kurtosis level up to 7.

During testing the battery is constantly cycled by charging and discharging to simulate normal driving conditions. All performance data is analysed by GM Test Engineers.

The Solution

- An LDS V8-640 system with a SPA-56K amplifier. Test level capacity 55.6 kN Random & Sine
- Two different sized head expanders that can handle up to $1.8 \times 1.8 \text{ m}$ (6 ft \times 6 ft)
- Two different sized slip tables also capable of handling up to $1.8 \times 2.4 \text{ m}$ (6 ft \times 7.8 ft)
- Two DeltaTron[®] Accelerometers Type 4513 used for feedback to the control system
- Five Miniature Triaxial DeltaTron[®] Accelerometers Type 4524 which are mounted on the battery pack for real-time monitoring and post-processing analysis

Of the system, Tony says, "One of the major advantages of the vibration system is that it takes typically less than two hours to change the slip table from horizontal to a vertical position. Alignment is critical. The testing profiles in the horizontal and vertical axes are slightly different". The head expander and assembly airlifts six inches from the armature via airbags between the head expander guidance frame and the shaker base. It is then a matter of moving the test specimen, rotate the shaker and fix it to the slip-table. Normal procedure would be to remove all head expander bolts and frame bolts – completely remove the entire head expander and guidance assembly and rebuild to the new configuration. Other buying criteria included:

- The large size of the expander head and the slip table easily accommodate the large battery unit
- Versatility. The system can quickly be converted for testing smaller components using the smaller expander and slip table
- Ability to reduce testing time sufficiently due to the controller's kurtosis capability
- Ability to operate at temperature extremes from -40 to $+140^{\circ}\text{C}$. A specialised thermal barrier copes with these extremes
- Ability to manage heavy off-centre loads
- Local service and support. Application assistance and shaker maintenance support ensure maximum operational time

The testing laboratory at Warren runs 24 hours a day and has an automatic shutdown functionality should anything go wrong. "The vibration test room," says Tony, "is used every day including weekends. We typically do the setting up during the day and run the tests overnight".

The Future

Fig. 3
*The insides of an OPEL
Ampera*



GM's commitment to hybrid technology is far reaching and has extended to GM's wholly-owned subsidiary, OPEL, and its production of the Ampera electric car in Europe. The prototype Ampera was built in Michigan and its battery tested at Warren. It is hoped that the Ampera will hit the European markets in 2011.

GM's commitment is, furthermore, reflected in its plans to be the first major U.S. automaker to design and manufacture electric motors, a core technology for hybrids and electric vehicles, and which will debut in GM's 2-mode hybrid vehicles (which operate on engine power, electric power, or a combination of both) in 2013. In a 2010 Press Release GM stated that the move to the 2-mode hybrid cars would "lower costs and improve performance, quality, reliability and manufacturability of electric motors". Tom Stevens, GM Vice Chairman for global product operations added, "In the future, electric motors might become as important to GM as engines are now. By designing and manufacturing electric motors in-house, we can more efficiently use energy from batteries as they evolve, potentially reducing cost and weight – two significant challenges facing batteries today."