TRANSPORTATION RESEARCH GROUP
CRASH RESEARCH SECTION

VERIDIAN ENGINEERING
(FORMERLY CALSPAN SRL CORPORATION)
BUFFALO, NEW YORK 14225

CASE NO. CA98-066

ELECTRIC POWERED VEHICLE CRASH

1998 FORD ELECTRIC RANGER PICKUP TRUCK

1993 BUICK CENTURY

LOCATION - STATE OF FLORIDA

CRASH DATE - NOVEMBER, 1998

ON-SITE INVESTIGATION

Contract No. DTNH22-94-D-07058

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points are coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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16. *Abstract*

This crash involved a 1998 Ford Electric Ranger pickup truck which struck the rear of a 1993 Buick Century. The Ford Electric Ranger was equipped with a traction battery pack consisting of thirty-nine 8-volt lead-acid batteries that developed 312 volts DC power to the motor/transaxle and vehicle accessories and weighed approximately 816 kg (1800 lb.). The battery pack was not compromised in the crash.

The crash occurred during the early afternoon hours in the month of November, 1998 in the State of Florida just south of a four leg intersection. The weather was sunny with no adverse conditions at the time of the crash. The roadway speed limit was posted at 64 km/h (40 mph). The driver of the Buick had stopped for an animal in the travel lane prior to the crash.

The frontal plane of the Ford Electric Ranger struck the rear of the Buick Century in a 60 percent right offset configuration resulting in a Collision Classification Code (CDC) of 12-FZEW-1 for the Ford and 06-BDEW-6 for the Buick. The output from the WinSMASH speed reconstruction program indicated that the Ford sustained a total delta V of 27.7 km/h (17.2 mph) and the Buick experienced a 41.7 km/h (25.9 mph) delta V, although the barrier equivalent values of 15.4 km/h (9.6 mph) for the Ford and 50.3 km/h (31.3 mph) for the Buick visually appeared to be more representative of the delta V.

The Ford was equipped with dual front air bags which did not deploy during the crash sequence. The 49 year old driver was using the manual three point lap and torso belt at the time of the crash and was not injured. This was reportedly the driver's first driving experience with an electric vehicle (EV).

The vehicle was towed from the scene as the result of the inertia shut-off switch being tripped during the crash sequence. The switch was located inside the vehicle behind the right kick panel and equipped with a red reset button. It was apparent that the switch was reset at the dealership following the crash as the propulsion system was operational at the time of this inspection.

17. *Key Words* Electric Vehicle (EV) Total delta 27.7 km/h (17.2 mph) 49 year old male EV driver Electrical propulsion system not compromised		18. *Distribution Statement* General Public	
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BACKGROUND

Calspan Operations of the Veridian Corporation notified the Crash Investigation Division (CID) of the National Highway Traffic Safety Administration (NHTSA) of a two vehicle crash involving an electric powered 1998 Ford Electric Ranger pickup truck and a 1993 Buick Century which occurred in the State of Florida. Calspan Operations became aware of the crash during a Calspan NASS Zone Center site visit to a NASS PSU. The Zone Center Representative was conducting a training exercise at a vehicle dealership when he was informed by the dealership personnel of a crash involving an electric vehicle (EV). As part of the training exercise, the PSU documented the damage profile of the EV vehicle and supplied crush data to the SCI investigator.

The CID directed the Calspan SCI team to immediately conduct an on-site investigation. A Calspan SCI investigator, who was coincidentally conducting an on-site investigation on another SCI crash investigation in Florida, concluded work in that case and arrived on-site the following day.

In preparation for the SCI investigation, negotiations were conducted with the municipal owner of the EV and the collision shop representative to delay repairs to the EV. The negotiations were partially successful as the municipality agreed, but the collision shop representative insisted that some dismantling of damaged components had to be made prior to the arrival of the SCI investigator in order to maintain integrity with repair information supplied to the municipality. Despite a compromise to limit dismantling to only the grille panel, the collision shop additionally removed the front bumper and the right front fender prior to the arrival of the SCI investigator. All other aspects related to the electric propulsion system, however, were not altered from the time of the crash to the arrival of the SCI investigator.

The dealership provided excellent support during the SCI investigation. An EV certified mechanical technician provided details concerning the operation of the EV system and accompanied the SCI investigator during the inspection of the undercarriage battery pack and power plant. He was instrumental in obtaining vehicle specification data from the Ford Motor Company in Detroit. Through his efforts, a dialogue was initiated between the SCI investigator and the manager of the Ford EV program in Detroit where it was learned that this crash represented the first known real world event involving a Ford EV pickup truck.

SUMMARY

This crash involved a 1998 Ford Electric Ranger pickup truck which struck the rear of a 1993 Buick Century that had stopped in the travel lane for a turtle. The Ford Electric Ranger was equipped with a traction

battery pack consisting of thirty-nine 8-volt lead-acid batteries that developed 312 volts DC power to the motor/transaxle and vehicle accessories. The battery pack was not compromised in the crash.

The crash occurred during the early afternoon hours in the month of November, 1998 in the State of Florida just south of a four leg intersection. The divided straight level roadway was designed with two through travel lanes in both directions, one left turn lane, and one right turn lane approaching the intersection in both northbound and southbound directions **(Figure 1)**. The crash occurred in the right southbound through travel lane. The asphalt roadway surface was dry with a 0.85 coefficient of friction. The weather was sunny with no adverse conditions at the time of the crash. The roadway speed limit was posted at 64 km/h (40 mph).

Figure 1 - View of pre-impact trajectory for the Ford prior to entering the intersection

The 49 year old male driver of the Ford Electric Ranger was traveling in southbound in the right through travel lane behind another vehicle. This reportedly was the driver's first experience at driving the EV. As the lead vehicle was passing through the intersection, the lead driver reportedly observed the 1993 Buick Century and swerved into the left lane. The driver of the Ford Electric Ranger then observed the presence of the 1993 Buick Century and attempted to apply the brakes. The vehicle was equipped with four wheel anti-lock braking system (ABS).

The frontal plane of the Ford Electric Ranger struck the rear of the Buick Century in a 60 percent right offset configuration which began at the right front bumper corner and extended 91.0 cm (35.8") to the left **(Figures 2 and 3)**. The Collision Classification Code (CDC) was 12-FZEW-1for the Ford and 06-BDEW-6 for the Buick. The output from the WinSMASH speed reconstruction program indicated that the Ford sustained a total delta V of 27.7 km/h (17.2 mph) while the Buick experienced a 41.7 km/h (25.9 mph) delta V. The delta V values, however, did not appear to be representative of the vehicle crush profiles. The barrier equivalent values generated by WinSMASH were considered more in-line with delta Vs experienced in the crash. The barrier equivalent delta V for the Ford was computed at 15.4 km/h (9.6 mph) while the Buick experienced a 50.3 km/h (31.3 mph).

Figure 2- On-scene view of the frontal damage to the Ford EV

Figure 3- On-scene view of the rear plane damage to the Buick

The discrepancy in delta V results was attributed to the increased stiffness parameters of the Ford which resulted from the addition of the traction battery pack to the frame structure and the increased vehicle curb

weight. The specified weight of a regular gasoline powered Ford Ranger (as listed in the *Gasoline Truck Index)* was 1374.4 kg (3030 lbs.) vs. the EV weight supplied by the Ford mechanical technician of 2177 kg (4800 lbs.). This weight was consistent with the 900 kg (2000 lbs.) listed in the Ford training manual for the traction battery pack and other associated components.

The impact speed of the Ford was computed by the trajectory algorithm of WinSMASH as 53.8 km/h (33.4 mph). This was consistent with the post impact travel distance and the degree of damage to both vehicles. The Ford came to the final rest position (FRP) 5 m (16') from the point of impact (POI) and rotated 5 degrees clockwise from its impact heading angle. The left tires remained on the roadway while the right side tires were on the adjacent grass shoulder. The Buick rotated 78 degrees counterclockwise and traveled 11.6 m (38.1') from POI to the FRP. It came to rest broadside to its original travel lane **(Figure 4)**.

Figure 4- On-scene lookback view of the Ford's and Buick's final rest position

The Ford was equipped with dual front air bags which did not deploy during the crash sequence. The driver was using the manual three point lap and torso belt at the time of the crash and was not injured.

The Buick was driven by a 45 year old female who was reportedly restrained by the three point lap and torso belt. She was not injured. The owner of the vehicle, a 87 year old female, was seated in the front right seat. She was also reportedly wearing the three point lap and torso belt at the time of the crash and sustained police reported minor injuries.

The minor to moderate damage to the front of the Ford Electric Ranger did not result in any compromise of the electric propulsion system. The battery pack which contained thirty-nine 8-volt batteries only exhibited a minor scrape as the result of contacting the right front axle torsion bar bracket. The vehicle was towed from the scene. The propulsion system, however, was fully operational at the time of inspection.

The collision shop representative drove the vehicle to the mechanical repair side of the dealership so that it could be placed on a lift for this investigation. The mechanical technician indicated that the vehicle was equipped with an inertia shut-off-switch which may have been tripped during the crash. The reset switch was located behind the right kick panel and was designed to be reactivated by pressing a red color button **(Figure 5)**.

Figure 5- View of inertia shut-off switch located behind the right kick panel

Fire/rescue responded and arrived on scene. They transported the 87 year occupant of the Buick to a local medical treatment facility.

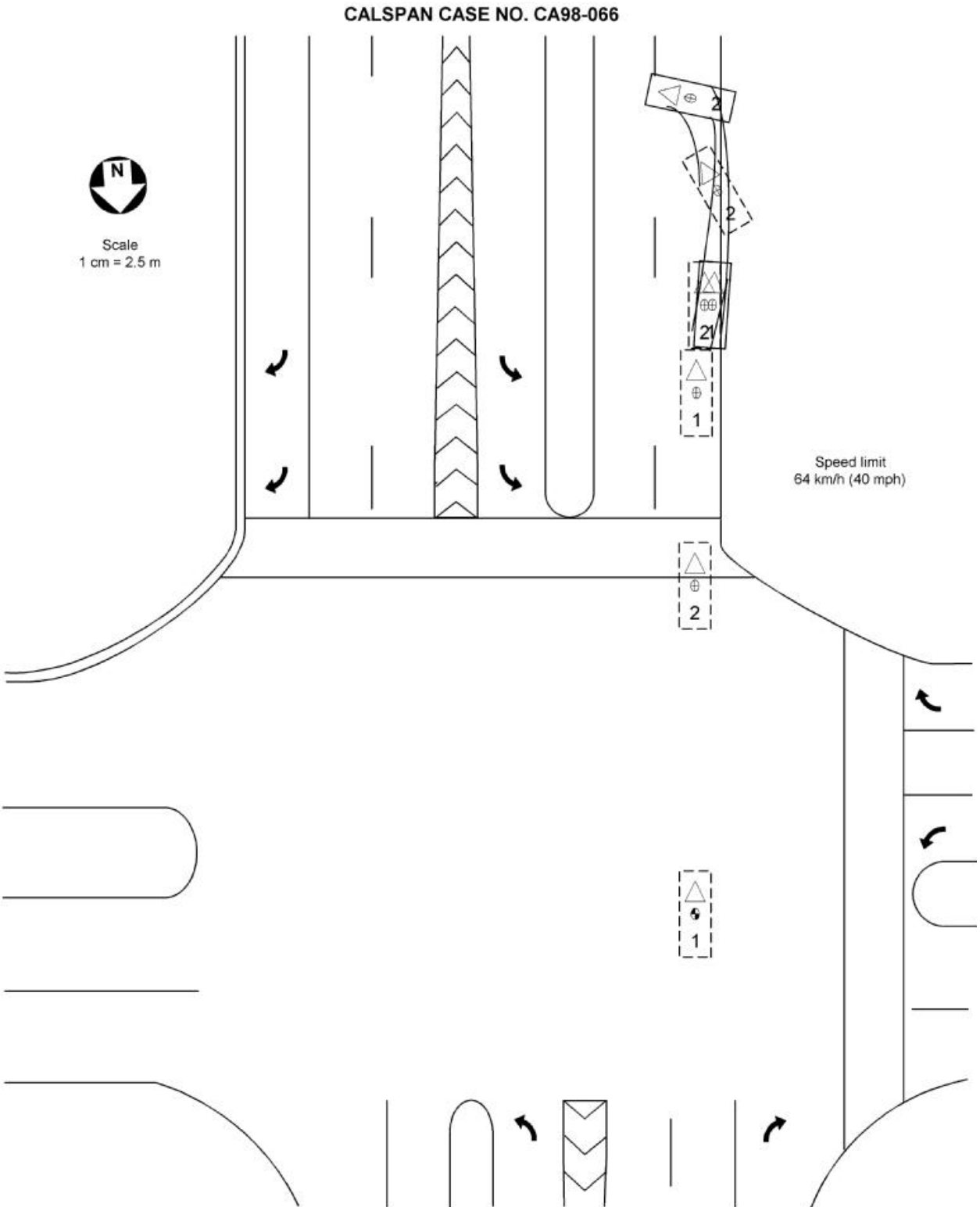

Figure 6 - Scene scaled schematic

VEHICLE DAMAGE DATA - FORD ELECTRIC RANGER

Exterior - Ford Electric Ranger

The 1998 Ford Electric Ranger pickup truck which was equipped with a dedicated electric propulsion system struck the rear of a 1993 Buick Century that had stopped in the travel lane for a turtle. The Ford was equipped with dual frontal air bags which did not deploy in the crash.

Exterior damage to the vehicle involved the front bumper, the grille, the recharging connector panel located in the right grille, the hood, right turn head light/turn signal assembly, and right front fender **(Figure 7)**. Although the housing for the recharging connector panel was damaged, the wires remained intact **(Figure 8)**.

Figure 7- View showing damage to the frontal plane of the Ford

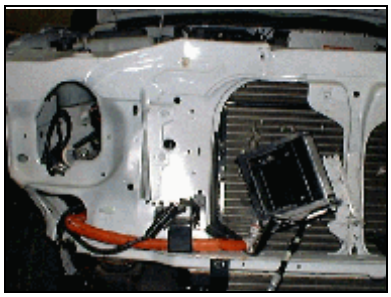

Figure 8- View of the recharging connector panel and associated wiring, and right SRS crash sensor

The maximum crush of 22.0 cm (8.7") was located at the right bumper corner. The crush profile obtained along the front bumper and upper radiator support is listed in the following table:

Crush measurements along the front bumper	C_1 = 0	C_2 = 1.3 cm (0.5")	C_3 = 4.5 cm (1.8")
	C_4 = 7.7 cm (3.0")	C_5 = 7.5 cm (3.0")	C_6 = 22 cm (8.7")
Crush measurements along the upper radiator support	C_1 = 0	C_2 = 1.6 cm (0.6")	C_3 = 9.5 cm (3.75")
	C_4 = 9.8 cm (3.9")	C_5 = 2.5 cm (1.0")	C_6 = 0

The Collision Deformation Classification (CDC) coding scheme for the Ford was 12-FZEW-1. The direct damage began at the right front bumper and extended 91.0 cm (35.8") to the left.

The recharging connector panel located in the right front section of the front grille panel was designed to blend in with the grille design. To accommodate this device in this location, however, the right crash sensor for the supplemental restraint system (SRS) was moved 17.8 cm (7.0") below its OEM position on the panel behind the grille. In this position, the leading surface of the crash sensor was coincidentally aligned with the top edge of the front bumper. During the crash, the front bumper moved rearward and contacted the crash sensor

housing resulting in a minor indentation which extended 4.1 cm (1.625") laterally across the face of the housing **(Figure 7)**.

Interior - Ford Electric Ranger

The interior of the Ford Electric Ranger pickup truck consisted of a bench seat with three point manual lap and torso belts in the outboard seating positions and a lap belt in the center seat. The adjustable D-rings for the torso belts were both in the down position. The restraint belt locking system was designed with a dual mode webbing sensitive inertia reel locking mechanism. The webbing sensitive locking mechanism responded positive in a rapid belt spool out test conducted during the inspection.

The supplemental restraint system (SRS) did not deploy during the crash sequence. The dual front redesigned air bags were intact and the SRS appeared to be fully functional. The air bag indicator light in the instrument panel cluster illuminated a 41 code which was decoded as "stored disconnect from sensor disconnect, run on demand test- system OK". This code was associated with the post crash disconnect of the front crash sensor wires due to mechanical repair activities.

The front right air bag was equipped with a keyed shut-off switch located in the lower center instrument panel area. A bright yellow warning label covered the keyed switch which warned that the air bag should be switched off when using a rearward facing child safety seat in the right front seat. When the label was pealed back during the inspection, the switch was located in the "on" position **(Figure 9)**.

There were two driver contact artifacts noted in the interior of the vehicle. The first contact involved a small area of abrasion below the temperature control panel in the center of instrument panel. This was attributed to contact by the driver's right hand during the crash sequence **(Figure 10)**. The second artifact was a 10.2 cm (4.0") vertical smudge mark on the left door glazing which was not associated with the crash sequence. The steering column did not appeared to be displaced or show signs of driver loading **(Figure 11)**.

Figure 9- View of the manual shut off switch for the front right passenger air bag

Figure 10- View of the abraded surface of the trim below the temperature control panel

Figure 11- Lateral view of the Ford steering wheel and column

EV PROPULSION SYSTEM - FORD ELECTRIC RANGER

The 1998 Ford Electric Ranger pickup truck was built on the 1998 Ranger gasoline powered platform. The gasoline engine was replaced by an array of electrical components in the engine compartment that included: a power distribution control; a power converter; an electro-hydraulic power steering unit; an air conditioning control; and a heater control **(Figure 12)**. A 12 volt lead-acid battery designated to operate the vehicle accessories such as wipers, fans, lights, radio, etc. was located in the forward left area of the engine compartment. Regenerative power to this battery was supplied by the converter located nearby. None of these components were damaged in the crash.

Figure 12- View of the electronic components

The recharging connector panel located in the front right section of the front grille panel was displaced during the crash as the result of direct contact damage. Although the housing for the connector panel was damaged, the wires remained intact.

The vehicle was equipped with a traction battery pack which consisted of thirty-nine 8-volt lead-acid batteries wired in series that produced 312 volts DC and were enclosed in a two piece non-conductive composite battery pack which consisted of a tray and cover bolted together. The 816 kg (1800 lb.) traction battery pack was supported by three lateral metallic straps that were bonded to the surface of the battery pack and located at each end with one located near the mid section. The ends of the straps formed a bracket which were mounted to the vehicle frame rails.

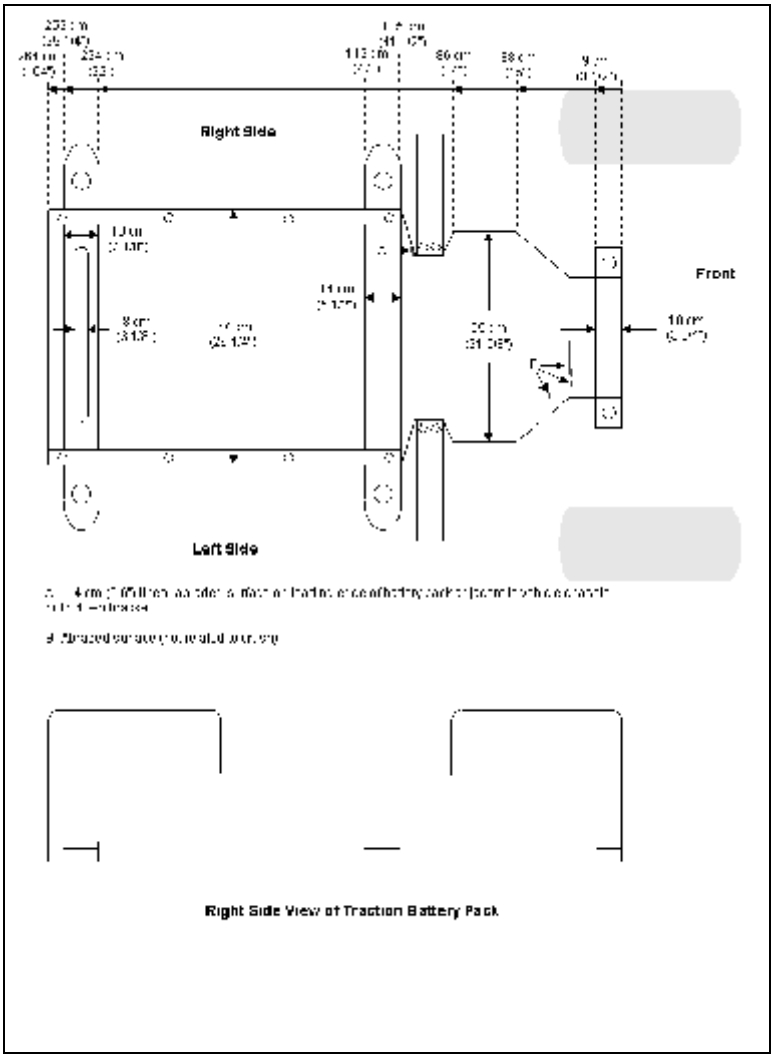

Figure 13

Crash related damage to the traction battery pack consisted of a small abrasion adjacent to the right front axle torsion bar bracket. It measured 1.4 cm (0.6") in length and was located on the leading vertical surface of the tray cutout for the torsion bar bracket and 9.8 cm (3.875") inboard from the right side of the tray **(Figures 13-15)**. This mark was attributed to contact with the torsion bar

bracket during the crash sequence. There were other abrasions noted at various locations of the battery pack which were attributed to contact with the installation rack during routine maintenance. The traction battery pack did not appeared to have been comprised during the crash.

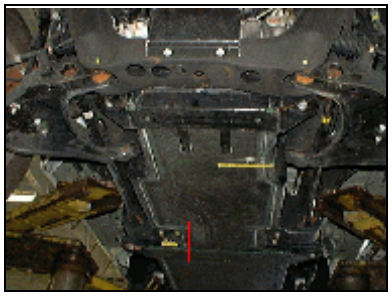

Figure 14- View of the traction battery pack looking from front to rear with the crash induced damage to the lower battery tray marked

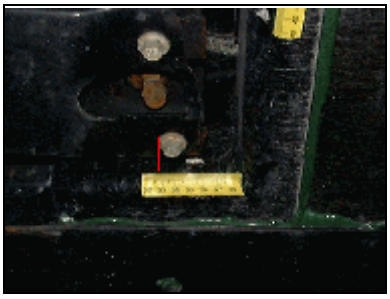

Figure 15- Close-up view of the contact damage between the front axle torsion bar bracket and the traction battery pack

The batteries in the traction battery pack were oriented lengthwise in the battery tray and arranged in a two level configuration **(Figure 16)**. The first level contained 27 batteries arranged in six rows beginning at the front of the battery pack and working reward. The first row (front of the tray) contained 3 batteries, the second row 4 batteries, and the remaining four rows contained 5 batteries in each row. Between battery row two and three, the traction battery pack narrowed to accommodate the front axle torsion bar mounting bracket. This resulted in a 19.1 cm (7.5") separation between the rows.

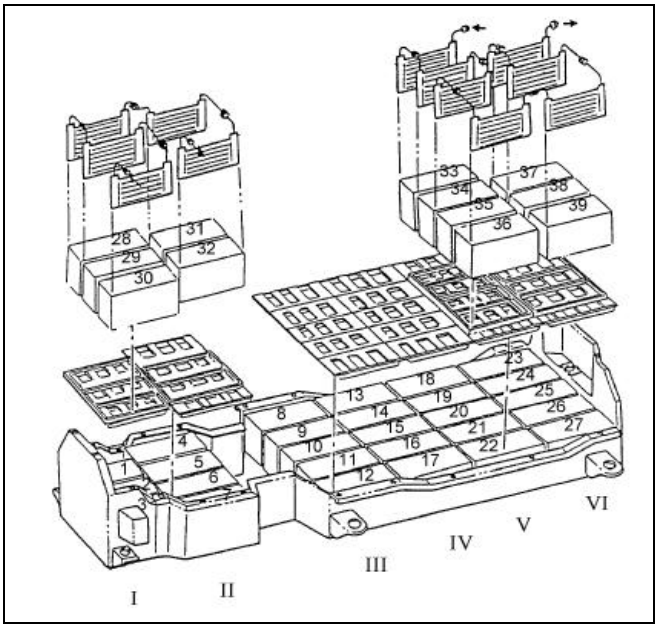

Figure 16- Schematic of battery layout in traction battery pack as illustrated in the Ford EV training manual

The remaining 12 batteries were located in the second level which were grouped in the fore and aft areas of the battery pack. The forward group consisted of three batteries located directly over the first row batteries followed by two batteries centered over the second row batteries. The aft group consisted of four batteries located over the fifth row batteries beginning at the left side and three batteries over the sixth row, again beginning at the left side.

The 264.2 cm (104.0") long traction battery pack was secured between the frame rails and was situated 69.2 cm (27.25") rearward from the end of the front frame rails and 22.7 cm (8.9") forward of the rear axle.

The lateral profile of the battery pack varied throughout the longitudinal length to conform with the OEM chassis design as illustrated in **Figure 13**. The widest dimension measured 66.7 cm (26.25") and was located rearward of the mid mounting bracket.

The vertical rise of the traction battery pack varied over its length to again conform with the OEM chassis design. At the front and rear sections, the vertical rise measured 38.1 cm (15.0") (due to the two level battery configuration) while the center area measured 24.1 cm (9.5").

The OEM rear axle of the truck was replaced by a tubular shaped alloy axle which was curved near the wheels to accommodated the transaxle rear wheel propulsion system **(Figures 17 and 18).** The axle was joined by a coupler to the rear portion of the each rear wheel assembly. The following identification label was attached to the forward surface of the axle:

F8Y84001
PART# AH
Supplier D1388
Code MICH Limited 98 EV
Serial# 167279

Figure 17- Overall view of the rear axle assembly and electric motor

Figure 18- Close-up view of the left rear transaxle and wheel assembly looking rearward from the right side

The single-speed constant-ratio transaxles with a 12.518:1 gear ratio were installed between the rear wheels and the high-efficiency 3-phase AC induction motor. The motor was bolted to a 11.4 cm (4.25") wide support bracket that was located 11.4 cm (4.5") rear of the traction battery pack. Power was supplied to the motor/transaxle by a primary power (2-pin) connector which was located at the rear of the battery tray. These components were not damaged during the crash.

The following labels were attached to the motor housing:

Traction Motor
Type 1 PV5133-4WS20W11
F8Y8-14B280-AC
Serial # J594318104016
Th.Cl.F rated battery voltage 250V
Manufactured by Siemens AG in Germany

Electric Transaxle F8YP-7002-AC
S/N 100057
Mfg. By GETAG
Gears of North America

The motor was rated at 67 kW (90 hp) which reportedly could accelerate the vehicle from 0-80 km/h (50 mph) in 12.5 seconds. The vehicle had a rated travel range of 93 km (58 miles) on a single charge without the use of air conditioning or heater, however, the mechanical technician indicated that the vehicle was typically reliable up to approximately 64-72 km (40-45 mph). The vehicle was also equipped with regenerative braking, four wheel ABS, and low resistance tires.

Located directly rearward of the motor was the Traction Inverter Modulator (TIM) which converts DC to AC for the motor. There was no disruption of the electrical cables between the converter and the motor.

The vehicle was equipped with a Power Reset Switch which was designed to disconnect the propulsion power during the application of a sudden force. The vehicle was towed from the scene which according to the mechanical technician was due to the switch being tripped during the crash. The technician indicated that his experience with the EV fleet suggested that the force necessary to trip the switch was minimal. He demonstrated the switch's low threshold by tapping the panel adjacent to the switch with a wrench which resulted in a tripped switch. The switch was located behind the right kick panel and was designed to be reactivated by pressing a red reset button. The location and operation of the switch was contained in the owner's manual as well as in a label located on the upper radiator support. The label read as follows:

This Vehicle is equipped with a Power Reset Switch.
Resetting this switch may resolve the problem.
Please refer to the Owner Guide for reset instructions

SHUT-OFF-SWITCH
Located under the
instrument panel
at the right hand cowl
side trim panel above
the carpet

The vehicle was also equipped with a 400-volt 250 amp fuse which was installed between batteries 20 and 21. This fuse was designed to protect the high voltage circuit. This fuse remained intact following the crash.

SPEED RECONSTRUCTION

The damage and trajectory algorithms of the WinSMASH 1.2.1 were used to calculate the delta V values and impact speeds. The delta V values generated by WinSMASH appeared to be overstated for the Ford and understated for the Buick. This discrepancy was attributed to the changes in the stiffness properties and increased weight of the Ford resulting from the addition of the traction battery pack and related electronic components.

The barrier equivalent delta V value for the Ford was computed as 15.4 km/h (9.6 mph) which appeared more representative with respect to the vehicle crush profile. Additionally, it should be noted that the SRS in the Ford did not deploy in the crash which was indicative that the threshold energy for system actuation had not been achieved. The longitudinal delta V of -27.7 km/h (-17.2 mph) computed by the Speed Change (Damage) algorithm otherwise should have been sufficient to deploy the system if the vehicle had experience that value. The outputs from the WinSMASH are included in the following table:

Ford Electric Ranger	**Speed Change (Damage)**	**Impact Speed (Linear Momentum and Spin out)**
Total	27.7 km/h (17.2 mph)	53.8 km/h (33.4 mph)
Longitudinal	-27.7 km/h (-17.2 mph)	
Lateral	0	
Energy	20,247 Joules (14,933 ft-lb)	
Barrier Equivalent	**15.4 km/h (9.6 mph)**	

Buick Century	**Speed Change (Damage)**	**Impact Speed (Linear Momentum and Spin out)**
Total	41.7 km/h (25.9 mph)	0 (stopped)
Longitudinal	41.7 km/h (25.9 mph)	
Lateral	0	
Energy	143,845 Joules (106,095 ft-lb)	
Barrier Equivalent	**50.3 km/h (31.3 mph)**	

VEHICLE DATA - 1993 BUICK CENTURY

The 1993 Buick Century sustained severe deformation to the rear plane. Damage components included: the rear bumper: tail light assemblies; trunk lid; both rear fenders; rear axle; left rear wheel; the roof; the left rear door, and disintegrated left rear door glazing **(Figures 19 and 20)**.

Figure 19- View of the damage to the rear plane of the Buick

Figure 20- View showing the depth of the crush profile

The crush profile obtained along the rear bumper is listed in the following table:

Crush measurements along the rear bumper	C_1 = 81.3 cm (32.0")	C_2 = 76.2 cm (30.0")	C_3 = 82.6 cm (32.5")
	C_4 = 47.0 cm (18.5")	C_5 = 22.9 cm (9.0")	C_6 = 0.3 cm (0.125")

The Collision Deformation Classification (CDC) coding scheme for the Buick was 06-BDEW-6. The direct damage began at the left rear bumper and extended 109.2 cm (43.0") to the right. The maximum crush of 85.7 cm (33.75") was located 34.3 cm (13.5") left of the vehicle centerline.

The interior damage was the result of occupant contacts and intrusion resulting from the crash sequence. The left and right front seat back supports were deformed rearward as the result of loading by the driver and right front occupant. The left rear seat back support was deformed forward 20 cm (8"). The right side surface of the center front seat arm rest was abraded from contact by the 87 year old female front right seat occupant during the crash.

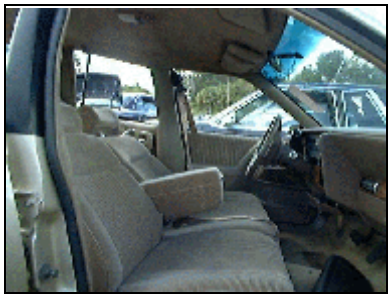

Figure 21- Lateral view of the front row seats showing the rearward deflection of the seat back supports