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Los Angeles Department of Water and Power
Department of Energy Site Operator Program
Final Technical Report
September 9, 1990 through March 31, 1994

The Los Angeles Department of Water and Power (LADWP) currently operates eleven electric vehicles (EVs); six (6) G-Vans, four (4) Chrysler TEVans, and one (1) Hybrid minivan. LADWP's participation in the United States Department of Energy (DOE) Site Operator Program involves the Hybrid electric minivan which was manufactured by Unique Mobility of Englewood, Colorado. and one Chrysler TEVan.

PROGRAM EFFORTS - UNIQ MINIVAN

LADWP took delivery of the UNIQ minivan on November 15, 1990. Since its delivery the UNIQ minivan has demonstrated severe range limitations. Initially the UNIQ minivan had a range of approximately 20 miles using only the batteries and approximately 35 miles range with the range extender in operation. Based on calculations performed prior to the vehicle's fabrication, Unique Mobility had estimated a range of 60+ miles for the vehicle with the range extender in operation. The vehicle, at one point, was shipped back to Unique Mobility for testing and service in an effort to remedy the range problem. No adjustments or modifications were made and the vehicle was returned with no improvement in range.

The range extender, a Honda powered generator, has required constant maintenance and at one point a complete overhaul was performed by LADWP's fleet maintenance shop. The vehicle, due to its range limitations, was relegated to around town errand runs and use in Electric Transportation Program displays. As of March 2, 1993 the vehicle had accumulated 3,448 miles.

During the first week of March 1993, the UNIQ minivan was driven on a daily basis for the purpose of establishing its reliable range. At this point, the range was consistently eight miles, in city traffic, without the use of the range extender. During the range testing it was noted that the instrument panel mounted battery voltmeter and the low battery warning light were not functioning.

The UNIQ minivan was taken out of service and turned over to LADWP's battery shop for the removal, inspection and service of the battery back. The removal of the battery pack was very difficult and require the services of three people for a period of four hours. Removal of the battery pack required not only removing the range extender's exhaust system, but more significantly an inch-by-inch jockeying of the battery tray back and forth and side to side in order to clear the vehicle's under structure as it was lowered. Once the pack was removed, the battery shop personnel found several problems which were either corrected immediately or postponed for repair at a later date. A list of the problems and actions taken is noted below:

DISCLAIMER

1) Batteries numbers 5, 6, and 7 (Sonnenschien 12v-160) were displaced. The batteries were repositioned.
2) The casing covers for batteries numbers 5 and 7 were cracked. The batteries were left as found as new batteries were to be ordered.
3) The positive cable from the battery charger to the batteries was pinched and the insulation was broken. The cable was repaired.
4) A fused shunt wire for the current meter was damaged. The wire was replaced.
5) The Plexiglas battery pack cover was burned. This damage had occurred in the past and had been previously repaired by installing rubber bushings between the batteries and the cover.
6) The shutoff voltage of the battery charger, at 142 volts DC, appeared to be too high for the gel cell batteries. This problem was reviewed with Soleq Corporation, the manufacturer of the battery charger and compared to product information relative to the batteries. The shutoff voltage was adjusted to 137 volts DC.
7) The DC to DC converter was found to be operational at all times, even when the ignition was turned off. The DC to DC converter was disconnected in order to stop current flow until power usage and correct operating criteria for the DC to DC converter could be identified.
8) A mounting bolt on the range extender was broken. The bolt was replaced using grade eight hardware.
9) The range extender's shock absorbing mount was leaking fluid. The shock was not repairable and a replacement unit was ordered.

A load test was performed on the battery pack to ascertain its condition. A preliminary resistance check of the power cables indicated high resistance, therefore, all of the battery pack power cables were replaced before the load test was actually performed. For the load test, the battery pack was loaded to 50 amps. After one hour and 28 minutes, battery number 7 was "jumpered out" due to low voltage (9.35 volts) and the test continued. After one hour and 54 minutes the voltage on batteries numbers 4 and 6 was low enough (9.03 volts and 9.45 volts respectively) to stop the test. The load test determined that the battery pack's capacity was approximately 66 percent of the nameplate rating (105 amp-hours vs. 160 amp-hours). Therefore, a decision was made to purchase new batteries: the type of batteries were to be determined later through research into the types and sizes available.

The old battery pack was reinstalled in the vehicle for use until a new set of batteries could be obtained. The battery pack installation took four people almost six hours to complete. The vehicle was then charged and driven 15 miles before being returned to service.

After being returned to service, the UNIQ minivan experienced a severe overcharge situation: over 48 hours the charger continued charging the batteries at 20 amps. Normally the batteries can be charged in 6 to 8 hours. The vehicle traveled only one half of one mile before running out of energy; the range extender was utilized to limp

home the vehicle. The battery shop found that the charger was charging at a rate of 20 amps at 137 volts, and that the battery tray was abnormally hot to the touch. After allowing the battery tray to cool, the pack was removed for inspection. Once removed the following items were found:

1) Some of the battery cell covers had popped off.
2) All of the batteries had warped casing sides
3) The batteries in the center of the pack exhibited signs of leakage at the side and top.
4) The batteries' gelled electrolyte had solidified into small chunks.

LADWP continued to investigate the possible causes of the battery pack's failure. One possible scenario was a charger malfunction on its own; the other possibility was a combination of having deteriorated batteries, new low resistance power cables, and a battery charger that uses battery pack peak voltage (137 volts) as a shutoff signal. In the first case, it is a simple matter of the battery charger overcharging the batteries which resulted in their failure. In the second case, LADWP explored the possibility that the condition of the batteries was such that they could not accept a full charge, and that the battery voltage never reached the shutoff voltage required by the charger thus overcharging the batteries.

LADWP initiated dialogues with Unique Mobility, the company that converted the vehicle, and Soleq Corporation which provided many of the electronic components including the charger, to try to obtain design information and wiring schematics for the minivan.

Due to the lead time required to procure new batteries and the uncertainty as to what caused the battery failure, LADWP temporarily installed nine group 27 heavy duty commercial batteries. This installation required extensive wood cribbing to keep the batteries from sliding around in a tray designed to hold nine group 8D batteries.

The temporary battery pack installation took two days, including all the power and control wiring. The pack was charged using the UNIQ minivan's onboard charger with a voltmeter connected across the main power leads for constant monitoring. The battery charger was manually disconnected when the battery pack voltage reached 142 volts (15.8 volts per battery, 2.63 volts per cell). The minivan was successfully test driven five miles and then recharged using the same method. To assure that there were no auxiliary loads on the battery while the vehicle was not being driven, the power feed to the DC to DC converter, which had been remaining on at all times, was disconnected.

During the first week of April 1993, the UNIQ minivan was driven once to determine the vehicle's range on the temporary battery pack and whether or not it could be used in any application. The range with the range extender turned on proved to be a disappointing five miles in city traffic.

Due to the limited range and the necessity of dropping the battery pack for recharging it was decided to remove the vehicle from service until the onboard systems were diagnosed and repaired and an appropriate battery pack was installed.

Our efforts to diagnose and repair the vehicle's electrical systems continued to be delayed due to difficulties in obtaining technical information from both Unique Mobility and Soleq Corporation. LADWP continued the ongoing dialogue with both companies in an effort to obtain appropriate documentation on the vehicle's various electrical systems.

LADWP pursued the possibility of installing various types and sizes of battery packs in the UNIQ minivan. One favorable alternative was the reinstallation of the larger battery tray that had been on the vehicle before the addition of the range extender. However, after contacting both Unique Mobility and Soleq Corporation it was learned that this particular aluminum battery tray had been disposed of. It was decided that the design and construction of a new battery tray was not warranted at this time. Further investigation into replacement batteries lead to the conclusion that the best battery for this application, that did not require modifications to or the redesign of the battery tray, was the Sonnenschien 12v-160, the same battery that the vehicle was delivered with.

At this point the purchase and installation of new batteries was put on hold until such time as LADWP would be able to properly diagnose and repair the vehicle's electrical systems. This task remained dependent on developing appropriate technical documentation for which LADWP required the cooperation of Unique Mobility and Soleq Corporation.

LADWP through its continued effort to develop the appropriate technical documentation pertaining to the vehicle's electrical system acquire from the Soleq Corporation a copy of the design notes generated during the conversion of the vehicle.

Based on the information received from Soleq Corporation, the installation of a battery system of higher capacity than the original one and the removal of the range extender was reconsidered. Due to the unavailability of the original aluminum battery tray or any design drawings associated with that tray it was again decided to replace the batteries with the same type as supplied with the vehicle, Sonnenschien 12v-160.

Further investigation into the availability of this particular battery lead to the determination that the Sonnenschien 12v-160 batteries that were manufactured in Germany had higher capacity and longer life than those manufactured in the United States. In order to achieve the best possible performance form the UNIQ minivan, LADWP investigated the possibility of procuring the Sonnenschien batteries that were manufactured in Germany.

LADWP continued to work to develop meaningful test and diagnostic procedures through the analysis of the vehicle design notes supplied by Soleq Corporation. Unfortunately the available information was not sufficient to enable LADWP to fully

develop the test and diagnostic procedures. Testing of the vehicle's electrical systems continued on a limited basis until the new battery pack was ready for installation. Much testing remained necessary, but required the battery pack to be installed so that various voltage readings and current use could be traced throughout the vehicle's systems. This process was expected to be vary tedious, as extreme caution had to be taken to prevent further damage to the vehicle's electrical systems, damage to the new batteries, and above all to ensure the safety of the personnel working on the vehicle.

In the pursuit of obtaining Sonnenschien 12v-160 batteries manufactured in Germany, LADWP found that Sonnenschien was producing a DF8D gelled-electrolyte battery rated at 225 amp-hour that were of the same physical size as the 160 amp-hour rated 12v-160. LADWP issued a purchase order for nine of the 225 amp-hour DF8D batteries. This increase in amp-hour capacity is expected to provide a noticeable improvement in the vehicle's range and thus its usefulness in a fleet type application.

During the month of February 1994, LADWP's battery shop individually tested each of the new Sonnenschien batteries before installing them in the minivan's battery tray. The battery tests indicated that all the modules were at or above rated capacity. The installation of the new batteries required minor modifications to both the battery modules and the battery tray, even though they were advertised as being of the same physical size as the original batteries. LADWP's automotive body shop modified the existing battery tray to accommodate the new batteries. The modifications consisted of removing the internal 3/4 inch thick plywood bulkheads and replacing them with aluminum sheet. The aluminum sheet was then covered with Fiberglas to provide added strength and to bond the aluminum sheet to the sides and bottom of the battery tray.

Once the new batteries were installed in the vehicle further in depth testing of the vehicle's electrical systems began. Initial tests indicated that many of the vehicles systems were unnecessarily interconnected and that there were portions of systems such as alternating current powered pre-cooling that were incomplete yet interconnected to required vehicle systems. This interconnection of systems and presents of partial systems that inter-reacted with required systems made trouble shooting and system diagnosis extremely difficult. To facilitate proper diagnosis of the required systems it was decided to eliminate the partial systems and remove the unnecessary interconnections between other systems. This process which is ongoing amounts to rewiring the vehicle's systems in a logical manner so that each system can function to its full potential without unnecessary inter-system complications.

Due to the complexity of various systems, which included duplication of functions and piggy backing of some systems onto others, it was decided to remove many of the existing cumbersome and complex system and replace those that are necessary with much simpler technology and rewire the vehicle based on a logical wiring schematic. This vehicle refit process is ongoing.

PROGRAM EFFORTS - CHRYSLER TEVAN

LADWP took delivery of four Chrysler TEVans between September and November, 1993. Of the four vehicles, two have experienced significant problems, one has had regular problems and the forth has experienced occasional problems. One significant issue that has affected all four vehicles since delivery and remains unresolved by Chrysler is the inability to charge the vehicle from a ground fault circuit interrupter (GFCI) equipped 220 volt single phase outlet. These safety devices are required by the City of Los Angeles building code on all electric vehicle charging facilities.

Most of the remaining problems have long since been identified and are of the repetitive nature. LADWP has had to replace ten Motor Control Units (MCUs) and eight Auxiliary Power Control Units (APUs) in the last six months. Fortunately from a safety stand point most of the failures have occurred while the vehicle was charging thus not leaving people stranded in the roadway. However after two on the road failures that left people stranded in busy traffic, LADWP has had to reevaluate our TEVan usage protocol.

Other reoccurring problems stem from the vehicle's battery watering system. This system is supposed to allow for battery gassing while recapturing any electrolyte and is supposed to fully rewater all the battery cells after the completion of a charge cycle. Even after a retrofit to the battery watering system reservoir the vehicle still experiences electrolyte boil over after heavy use and after charging. The reservoir also leaks fluid if the vehicle is on an incline such as in a driveway or being loaded onto a roll back transporter. It has also been found that the MCU does not always activate the battery watering pumps upon the completion of a charge cycle thus not adequately watering the batteries, this is especially prevalent on the Ni-Cad battery equipped vans.

These previously identified and documented problems are not unique to LADWP's TEVans. The other utilities that participated with the Electric Power Research Institute (EPRI) in supporting Chrysler's EV program are experiencing the same as well as other reoccurring problems with their TEVans.

LADWP in conjunction with the other utility TEVan users are continuing to work through EPRI to get Chrysler to adequately address the design and support problems that are hampering the usefulness of the TEVan program.