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Airport Passenger Loading Bridge Power-Sharing Demonstration

Atlanta Hartsfield International Airport

Technical Report

Airport Passenger Loading Bridge Power-Sharing Demonstration

Atlanta Hartsfield International Airport

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PRODUCT DESCRIPTION

This report documents the second phase of a two-part project that began with a power utilization study in 2004 and concluded with a power-sharing demonstration in 2005. The project demonstrates fast charging of electric airport ground support equipment (GSE) using existing electrical service on the passenger loading bridge at Atlanta Hartsfield International Airport Gate T-7, South Terminal.

Results & Findings

The demonstration monitored vehicle usage, performance, battery state-of-charge and temperature, as well as energy usage and power demand on the circuits. As a rule, the vehicles were sufficiently charged except at times when operators failed to plug them in. The vehicles performed without interruption. Battery temperatures never exceeded manufacturers' warranty limits.

To demonstrate that power could be shared by the Jetway™ and the fast charger without conflict, the project monitored current and all power usage at multiple locations along the system. Measurements started at the main power busway, then moved to the main feed into the serving switchboard, the feed out to the Jetway, and the charger disconnect switch mounted on the Jetway at the apron level.

Analysis of the data collected at the Jetway and the charger monitors demonstrated that the charger-disconnect was working as designed. The demonstration measured every single-cycle maximum, minimum, and average over a period of time. While there were some short-duration instances where maximum current across all three phases exceeded the 100-amp rating of the circuit at the Jetway, they were short-duration transients from the Jetway motor inrush. These peaks were not associated with the charger current and would have occurred regardless of the existence of the charger.

The charger had very little impact on the peak circuit loading at the switchboard main breaker. The data show that even an additional charger could be added to the circuit with little impact on the switchboard main breaker. The impact of the charger on the busway was minimal, and engineers determined that even multiple chargers could be installed with negligible impact on busway peak loading.

Challenges & Objective(s)

This report includes discussion of the many variables and considerations that must be factored in to any decision to implement fast charging at an airport or to attempt a power-sharing arrangement at an airport gate. The document also includes discussion of how to compare the cost of conventional charging to fast charging: factors such as equipment purchase price, installation, and application must be considered.

Applications, Values & Use

This report provides a useful summary of the considerations involved in this particular demonstration and notes other factors that may impact decision-making at other locations.

EPRI Perspective

This project shows how EPRI's unique relationships with industry foster research and development (R & D) collaborations that benefit all participants. Such joint efforts result in valuable shared information that helps advance utility and industry efforts to overcome technology barriers and build the industrial electric transportation market.

Approach

The project team's primary goal was to demonstrate that power-sharing could occur without interrupting passenger loading and aircraft service needs while also meeting charging needs of electric GSE. Another goal was to test expectations that a power-sharing arrangement could be more cost-effective than dedicated infrastructure.

The idea of sharing passenger loading bridge power with another device—even with an electric GSE charger—is not necessarily new. The project team's approach, however, is the first to share loading bridge power with a fast-charging unit, which requires significantly more power than a standard charger. This approach also is the first to incorporate an interface device that disconnects power to the fast charger when the bridge is operating.

A number of partners contributed to the project: AeroVironment, Inc.; Averest, Inc.; Cleveland Electric Company; Delta Air Lines, Inc.; EPRI Solutions; FMC Jetway; Alabama Power; and Georgia Power.

Keywords

Industrial vehicles
Electric transportation
Airports
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Ground support equipment

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Additionally, the authors wish to acknowledge the late Robert Bellenger for his wisdom and guidance in establishing this project.

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1 PROJECT BACKGROUND

This report documents the demonstration phase of a two-part project that began with a power utilization study in 2004 at Atlanta Hartsfield International Airport Gate T-7, South Terminal.

Demonstration Objectives

The objectives were as follows:

1. To demonstrate the use of existing airport passenger loading bridge infrastructure to power both the bridge and an electric ground support equipment battery rapid charging system.

2. To determine if sharing the loading bridge infrastructure would reduce installation cost of a rapid charging system for electric airport ground support equipment.

Need for this Research

Many U.S. airports are located in metropolitan areas that have difficulty meeting federal air quality standards. In response, airports and airlines are seeking to reduce emissions from their ground support equipment (GSE) fleets, which represent a significant portion of the emissions generated. One solution is to replace existing diesel- and gasoline-powered GSE with battery-powered electric alternatives.

In addition to seeking to reduce emissions, airlines are trying to reduce operating costs and are turning to GSE electrification because it can provide savings. Although electric GSE generally comes with a higher capital cost, over its lifetime, its represents a positive return on investment.

For a complete fleet conversion to battery-electric to occur, rapid charging of the batteries in electric GSE will be required to meet the airlines' daily demands. Rapid charging systems can be less expensive to install and operate, but their initial capital cost is higher than standard charging systems. In addition, their higher power requirements may necessitate infrastructure upgrades; power needed for such systems may not always be readily available at the gate.

Passenger loading bridges at most airports already have dedicated electrical infrastructure that is typically underutilized because the bridges are in use only for short periods of time. Therefore, airport and airline operators are interested in determining if the infrastructure that powers a passenger loading bridge may also be sufficient to power a rapid charging system when the bridge is not in use.

By demonstrating that a typical passenger bridge has sufficient capacity to support the additional fast charging demand, a method could be developed for these two systems to share available infrastructure. Sharing this power would greatly reduce the cost associated with installation of rapid charging systems required to operate electric ground support equipment.

Project Genesis

In the months preceding this project launch (in early 2004), Delta Air Lines, which operates approximately 110 electric ground support vehicles in Atlanta, had tested a PosiCharge fast charging unit at a nearby gate. The airline also had positive fast charging experiences elsewhere with a 60kW single port charger. The airline had been considering investing in a significant number of multi-port fast charging units for placement at different terminals and gates throughout the airport.

At the same time, Georgia Power was planning a significant power overhaul and upgrade with a third power supply line to the busy airport. All involved wanted to ensure that there was sufficient power to meet Delta's need, should the airline go forward with its fast-charging investment. They also were unsure of the availability of physical space needed for equipment such as transformers and ducting to accommodate the new load.

The uncertainties led to conversations about possible creative solutions, including the feasibility of sharing power with the existing loading bridge. A two-part project was created. The first part, a monitoring study of power usage at Gate T-7, was launched in early 2004 and is documented in EPRI Report 1008776. The following report documents the second part of the feasibility study, the demonstration.

Project Significance

The idea of sharing passenger loading bridge power with another device—even with an electric ground support equipment charger—is not necessarily new. This demonstration, however, is the first to share loading bridge power with a fast-charging unit, which requires significantly more power than a standard charger. It is also the first to incorporate an interface device that disconnects power to the fast charger when the bridge is operating.

Most passenger loading bridge circuits in Atlanta are sized for 60 amps to 100 amps routinely. Loading bridge power is sometimes shared with 400 Hz systems, which provide auxiliary power to airplanes parked at the gate. Such power-sharing arrangements are usually part of the original terminal design. There is no potential conflict or competition for power because the 400 Hz systems are used to condition the airplane cabin air at times when the bridge is not typically needed. Such power-sharing arrangements are in use at Atlanta's international terminal, Concourse E.

Power Monitoring Study Results

Details of the first phase of this study are available in EPRI TR-1008776.

In summary, the study found that power delivered to a Jetway™ may be available 79.5% of the time for fast charging. Power use on loading bridges is sporadic; the greatest power need is when the bridge is in horizontal drive mode.

Load projections indicated no equipment overloading as a result of using chargers at all Jetways in the T-Gate South terminal. Projected equipment loading was highest for transformers serving the T-Gate South terminal with projected loading reaching 59% of usable transformer capacity.

The power monitoring study noted that the next step would be to demonstrate the feasibility of power sharing. For the power-sharing demonstration to be successful, the monitoring study noted that the Jetway and rapid-charging system must communicate with each other and ensure that the Jetway always has first priority for available power. It was also noted that sufficient uninterrupted charging time was needed to fast-charge and meet the duty cycle of the ground support equipment located at the demonstration gate.

2
PROJECT DESCRIPTION

Following on the results and recommendations of the power monitoring study, project participants developed and implemented a plan to demonstrate power-sharing feasibility and verify the previous findings.

Participants included AeroVironment, Inc., maker of the PosiCharge fast charging system; Atlanta Airlines Terminal Corp.; Averest Inc., on-site representative for PosiCharge; Cleveland Electric; Delta Air Lines, Inc.; EPRI; EPRI-PEAC; FMC Jetway Inc., manufacturer of the passenger loading bridge; Alabama Power Co.; and Georgia Power Co.

Application Description

The demonstration took place at the same location as the earlier power monitoring study, Gate T-7 in the South Terminal.

Power Delivery

As described in EPRI TR-1008776 the source of electricity to the T-Gate South terminal at Atlanta Hartsfield International Airport is Georgia Power's Willingham substation. The Hartsfield substation serves as a backup. Three 2000-kVA transformers form a 480/277-volt secondary network bus, which supplies four main switches in the main electrical room, located on the terminal's apron level between Gates T6 and T5.

Figure 2-1 shows the power delivery schematic. Busduct A and Busduct D are the main power feeders. Busducts B and C are standby feeders. Busduct A provides power to Switchboard 2DSA, which feeds Jetway 7.

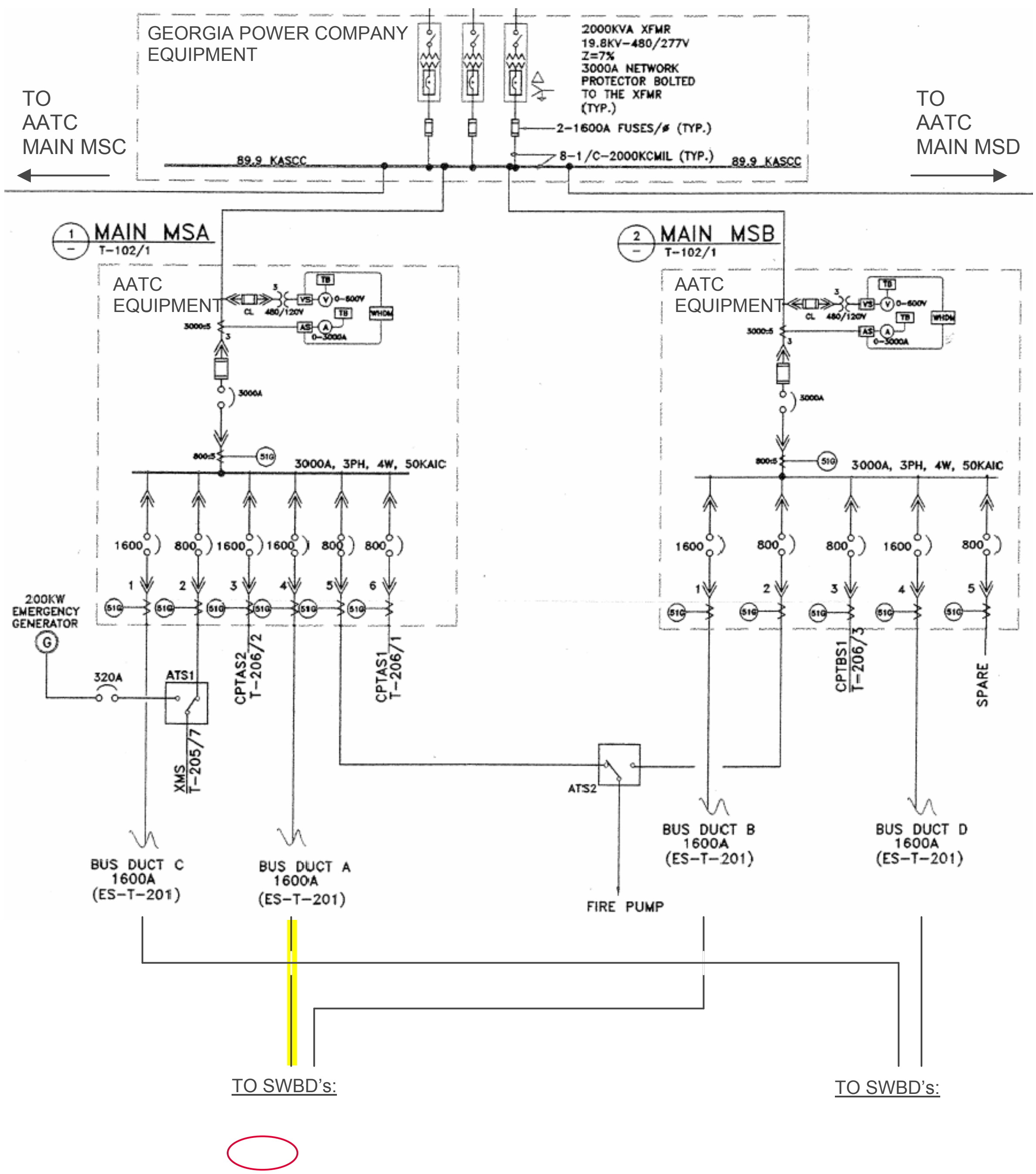

Figure 2-1
Schematic of main power feeders, busducts and switchboards, T-Gates South terminal

Passenger Loading Bridge

A key part of this demonstration was to ensure that the charger would never compete with the loading bridge for power, potentially delaying aircraft operation. Project partners determined that a simple power interruption device could be installed on the bridge to disconnect power to the charger when the bridge was in operation. This solution was not uncommon, since passenger loading bridges often share power with 400 Hz systems that provide ground power to airplanes at the gate. (The Jetway at Gate T-6 also had a 400 Hz system installed on its underside, however, this particular 400 Hz system was on a separate power circuit and was not sharing power with the Jetway.)

To ensure that the power stayed with the bridge when it was needed, FMC Jetway designed a relay switch that takes the signal of a horizontal drive contactor and closes when the loading bridge goes in to horizontal drive mode. The inter-opposing relay was housed in a simple disconnect box and installed on the Jetway bridge.

This was a relatively simple and inexpensive solution; most bridges already have spare electrical wiring that can be used for any number of purposes. In this case, the wiring enabled the Jetway bridge signal to communicate with the PosiCharge MVS system. For this demonstration, Jetway installed the disconnect box, a function that the company provides in other settings, as well.

Charger

The demonstration used a PosiCharge 60kW Multi-Vehicle System (MVS) comprised of a main power server and five dual-port power stations capable of charging up to 10 vehicles simultaneously. The charger is designed to take external inputs through an auxiliary control board, so a simple software modification ensured that when the bridge relay closed in horizontal operation mode, the charger would stop charging and go into idle mode. Vehicles would remain connected and in communication with the charger but their batteries would not receive power.

The charger was an older unit that had been delivered to Atlanta for a planned demonstration prior to September 11, 2001. It had been in storage since its delivery, as the airline was unable to commit time and resources to the demonstration in the years immediately following the September 11, 2001 terrorist attack. Newer MVS units operate at up to 80 kW.

Vehicles and Batteries

Ten electric ground support vehicles—two belt loaders and eight baggage tractors—used the fast-charging system during the demonstration. The belt loaders' battery capacity was 340Ahr. The baggage tractors' battery capacity was 500Ahr.

The vehicles, which were part of Delta's existing fleet and were not "fast-charge ready," were modified to accommodate fast charging. Charge connectors were changed and PosiCharge Battery Monitor and Identifiers (BMIDs) were installed on the batteries to enable communication between the battery and the charger.

The cost of the modifications was approximately $500 per vehicle: $400 for the BMID, $50 for the connectors, and $50 for installation. Had the vehicles been new, ordered as fast-charge ready vehicles, modifications and any associated costs would have been minimal.

Energy Monitors

For this demonstration, four power monitors were installed to monitor energy usage at four critical junctures: at Busway A, at the main feed into Switchboard 2DSA, the feed out to Jetway 7, and on the charger disconnect switch mounted on the Jetway at the apron level feeding the fast-charger itself, as shown in figure 2-2.

With the exception of the monitor located on the Jetway at the charger disconnect switch, data from all energy monitors were accessible on a daily basis through a telephone line connection.

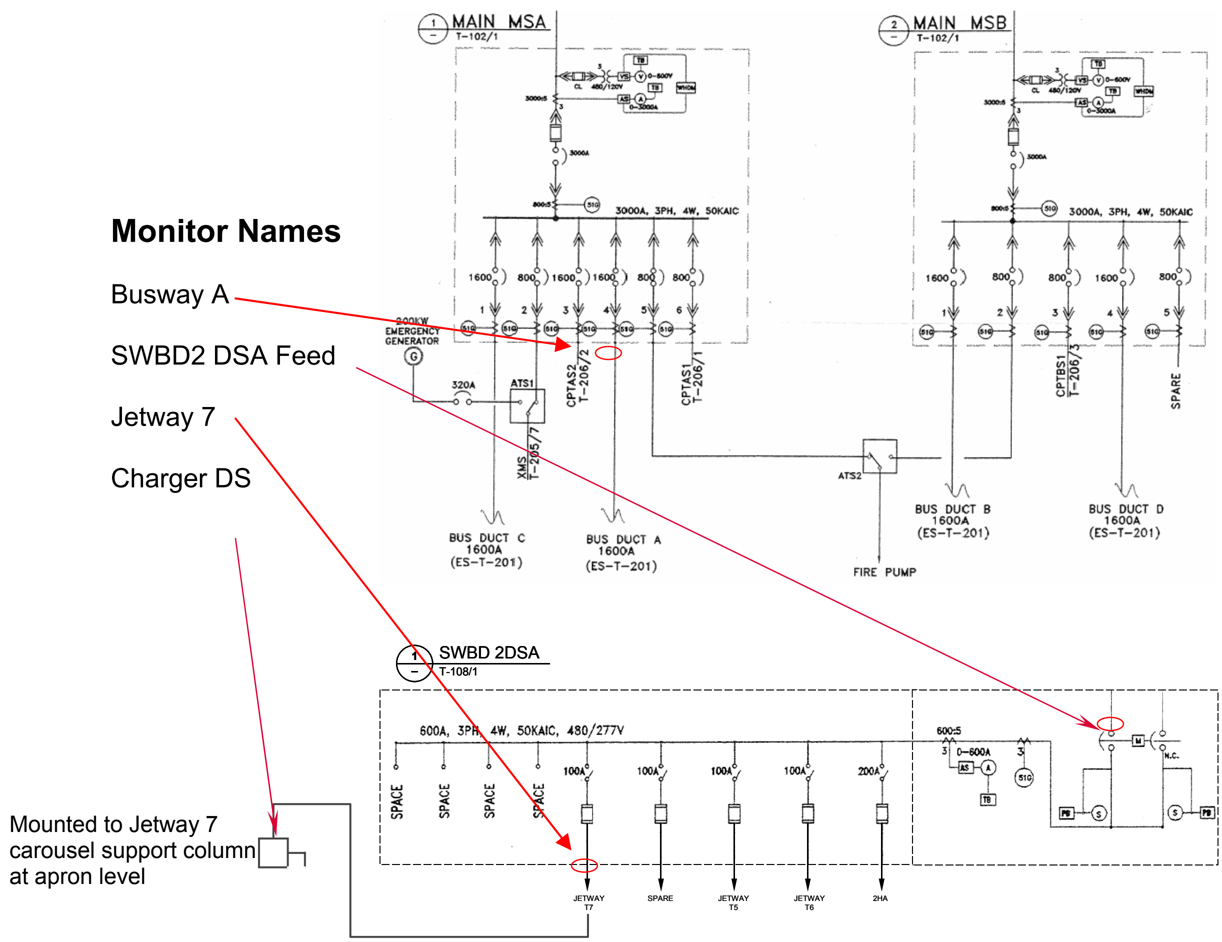

Figure 2-2
Energy monitor placement at four locations

Installation

Working together, Georgia Power and Cleveland Electric completed installation of the fast-charging power server and five dual-port power stations in October 2004. The partners worked closely to identify best placement for the individual power stations to ensure convenient charging access for Delta ground support crew while also minimizing crash risk and reducing the distance and resulting cabling costs between each station.

This installation benefited from existing building and site construction features that allowed three of the power stations to be installed on a sidewalk, away from vehicular traffic, as shown in Figure 2-3. A building overhang provided the perfect feature from which to hang conduit. Other locations without such an overhang from which to suspend cables might require significant concrete cutting to bury cables, or retractable cables, so that vehicles do not drive over them.

Figure 2-3
Dual Port Station

Figure 2-4
Power server (l) and station (above)

Among the site considerations were whether to install bollards to protect the power server—partners decided bollards were not necessary since it was not in a high traffic area (figure 2-4)—and for the cabling to be suspended from hangers under the Jetway. Other installation steps included the installation of the charger disconnect on the Jetway bridge, the energy monitors at all four locations and final system tests.

The system was operational by late November.

Installation Challenges

Georgia Power's experience with a previous fast-charging system installation at Emory University benefited this project installation. Installation personnel learned from their Emory experience that they would need flexible, thick insulation cable and conduit to accommodate the high DC current between the power server and the individual power stations. While the ideal distance between each power station is five to 10 feet, the actual distance can be as much as 20 feet, requiring a significant amount of cable and driving up installation costs, as discussed in Chapter 5.

Beyond increased cost, the size of the cabling and conduit presented challenges for the installation team. The enclosures that connected the conduit to the charger were 2.5 inches in diameter. This meant that the conduit could be no larger. The thick cable required for the DC current did not feed well into the 2.5 inch conduit. Electricians struggled to feed the cable though the conduit and ultimately spent more time than they would have, had they been working with 4-

inch conduit. Larger conduit was not an option in this demonstration, however, because of the 2.5 inch connectors on the charger.

One other installation challenge that any future airport demonstration of this kind should consider is the added time, expense, and frustrations or complications associated with getting workers through airport security to conduct their work at the demonstration site.

Demonstration Operation

Although the system was operational in early December, little, if any, charging was performed using the system prior to Christmas.

Equipment Function

All equipment performed as expected, with no disruption of service, un-charged vehicles, or tripped breakers. During the initial system test, there was a problem with power getting to the charger disconnect circuit. The engineers determined that it was not due to system design but to an unforeseeable break in the wiring on the Jetway bridge. The bridge is 25 years old, and it was determined that modifications made at some point in the past were not shown on the building schematics. Once this problem was resolved, the system worked flawlessly.

Ironically, during the time when the charger disconnect relay was not functional, power was provided simultaneously to the Jetway and to the charger. Because they were both receiving power, both the Jetway and the chargers were operating at the same time on a few rare occurrences. Even during these few times, there was never a demand for more power than was available.

In addition to the fast charging regime, the system was set up to provide a weekly equalization charge on Sundays. Equalization is the process of charging batteries to equalize the voltage across individual cells to restore balance and preserve battery life.

User Feedback

This installation introduced electric GSE and GSE charging to an area of the airport that had previously not used such equipment. GSE drivers at Delta had used electric equipment at other locations, so although it was new at this location, drivers were familiar with the need to plug in their vehicles.

Their only complaint was that they are unable to plug their vehicles in while seated in the vehicle. The system is specifically designed so that drivers have to get out of their vehicles to plug or unplug the chargers – as a safety precaution. When exiting the vehicle, they are more likely to set the parking brake, which reduces the potential for the vehicle to roll away while charging.

Drivers were not given any formal training in operating the charging system. When the PosiCharge representative was on site during installations and periodic equipment checks, he answered occasional questions from equipment operations.

This demonstration was part of a process that Delta Air Lines is using to consider a large-scale installation of fast charging in Atlanta. Decisions about where to install fast chargers will be based on factors such as vehicle usage and demand. For example, demand is much greater at the E Concourse due to operational changes that increase the duty cycle and the distance to baggage claim. During this demonstration, observers noted several cases of drivers assigned to the E Concourse stopping by in hopes of giving their vehicles a quick charge boost (something that could not occur because their equipment was not fast-charge ready). The fact that drivers wanted to try the fast charging system speaks to the need; on the E Concourse, drivers now have been known to plug their vehicles in to a conventional charger for as little as five to 10 minutes, with the hope of boosting their batteries. This practice, coupled with the deep discharge that occurs in this demanding application, taxes the lead-acid batteries.

Power Monitoring

Power monitoring began in late November 2004 at the three monitoring locations connected by phone lines. Data at those locations was downloaded daily. Engineers downloaded data from the fourth monitor, at the charger itself, on a weekly basis after Christmas. Official monitoring continued from December 10, 2004 through February 25, 2005. During the last week of the test, from February 18 – 25, the team switched from 30-minute samples to one-minute samples.

The only power monitoring challenges encountered were with the monitor located on the charger. Because it was not hooked up to a phone line, the team could not easily access the data. It required significant time and effort to physically go out to the site to collect the data. For this reason, the one-minute sampling that occurred on the three other monitors during the last week of the test did not occur at this monitoring location.

3
RESULTS

The demonstration team monitored vehicle usage, performance, battery state-of-charge and temperature, as well as energy usage and power demand on the circuits.

Vehicle Usage

Two beltloaders and eight baggage tractors were used in the demonstration. As a rule, the vehicles were sufficiently charged except at times when operators failed to plug them in.

Battery temperatures never exceeded manufacturers' warranty limits as the fast-charging systems are programmed to ensure that a battery never exceeds the maximum temperature allowed by the manufacturer.

Table 3-1 summarizes the charge history of all 10 vehicles early in the demonstration, between December 13, 2004 and January 10, 2005. The column heading EBUs (equivalent battery usage) references a vehicle's daily battery usage relative to its capacity. For vehicle 220, for example, equivalent battery usage of 0.4 means the vehicle used 40% of its battery capacity every day.

The three highlighted vehicles in Table 3-1 are those for which better data was available, enabling more detailed analysis. Figures 3-1 through 3-8 show the average charge returned and charge time; average charge and battery temperature; vehicle daily use; and battery state-of-charge on the highlighted vehicles during the December 13 to January 10 timeframe.

Table 3-2 summarizes the charge history of all vehicles later in the demonstration, between February 12 and March 5, 2005. Again, the highlighted vehicles represent those for which the most data is available. Figures 3-9 through 3-18 show the average charge returned and charge time; average charge and battery temperature; vehicle daily use, and; battery state-of-charge on the highlighted vehicles during the February 12 to March 5 timeframe.

Table 3-1
Charge History Summary 12/13/04 – 1/10/05

Veh. ID	Batt. Cap	Charge Ahr	Days	Total Charge Time	Avg Batt Temp	Max Temp	Min SOC	Avg Initial SOC	EQ Event	Fast Charge Events	Avg. Daily Use	Avg. Daily Chg. Time	EBUs
220	500	2749	22	26:27:16	94.0	122	0	67.9	0	35	145.8	1.40	0.4
57024	340	352	21	7:35:39	52.8	69	34	65.2	0	16	19.6	0.42	0.1
57025	340	244	20	7:33:15	59.9	89	9.7	74.3	2	28	14.2	0.44	0.1
77202	500	1589	6	19:48:38	97.7	118	0	67.8	0	40	309.0	3.85	0.8
77222	500	3561	23	36:01:57	90.6	122	27.6	63.7	0	74	180.6	1.83	0.5
77226	500	4046	22	36:54:36	78.3	105	40.6	78.7	0	51	214.6	1.96	0.5
77227	500	4399	23	48:10:16	92.3	122	27	72.9	1	53	223.1	2.44	0.6
77258	500	2760	22	27:02:53	88.0	111	26.2	66.8	1	39	146.4	1.43	0.4
77260	500	3200	18	45:58:19	106.9	147	0	60.6	2	45	207.4	2.98	0.5
77263	500	4610	23	45:00:35	88.7	116	15.2	70.9	0	53	233.8	2.28	0.6

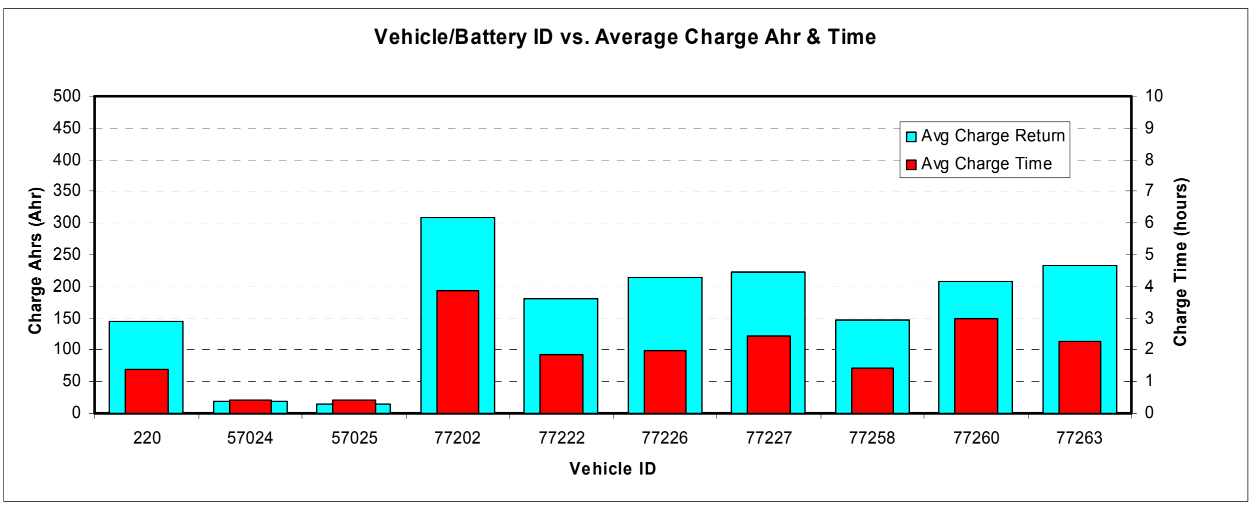

Figure 3-1
Average charge returned and charge time, by vehicle, 12/13/04 – 1/10/05

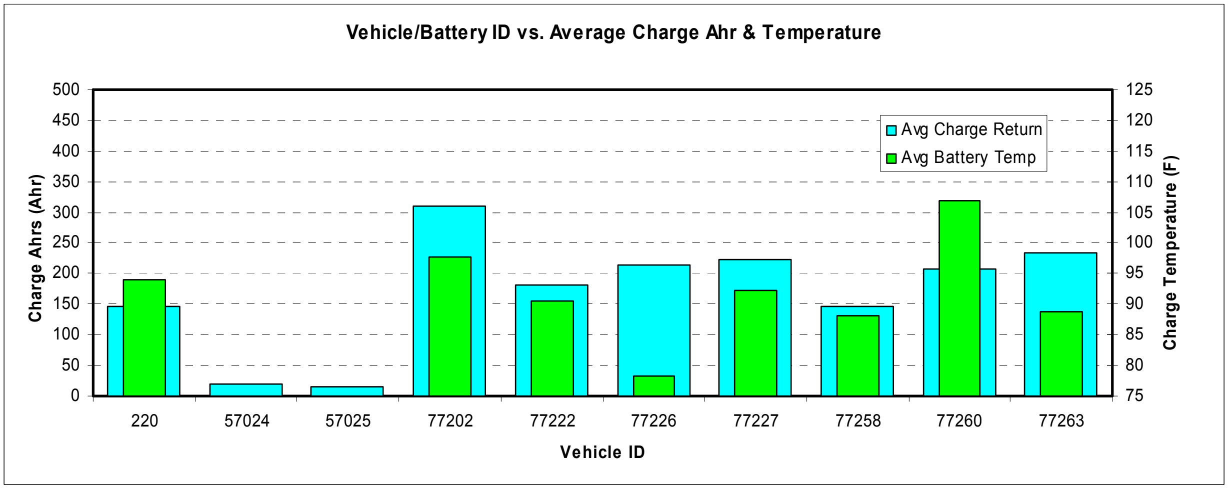

Figure 3-2
Average Charge Ahr and battery temperature, all vehicles, 12/13/04 – 1/10/05

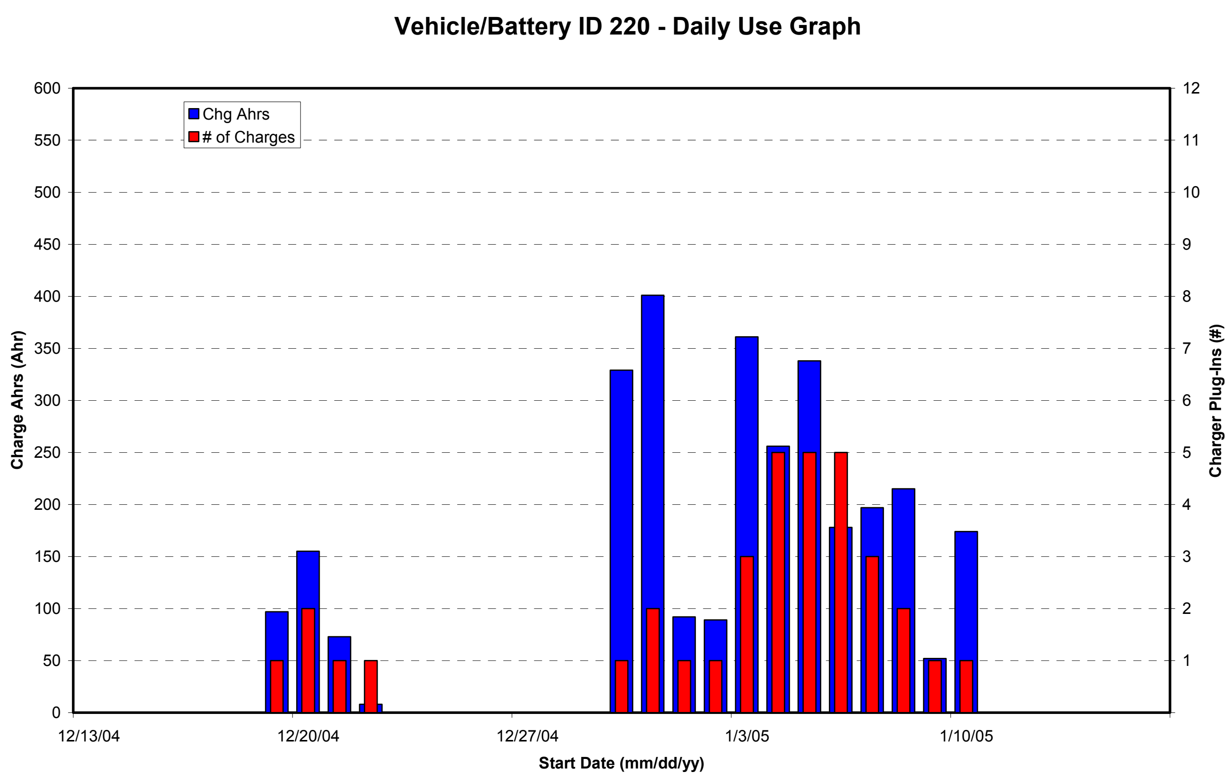

Figure 3-3
Number of charges and Ahrs, Vehicle 220, 12/13/04 – 1/10/05

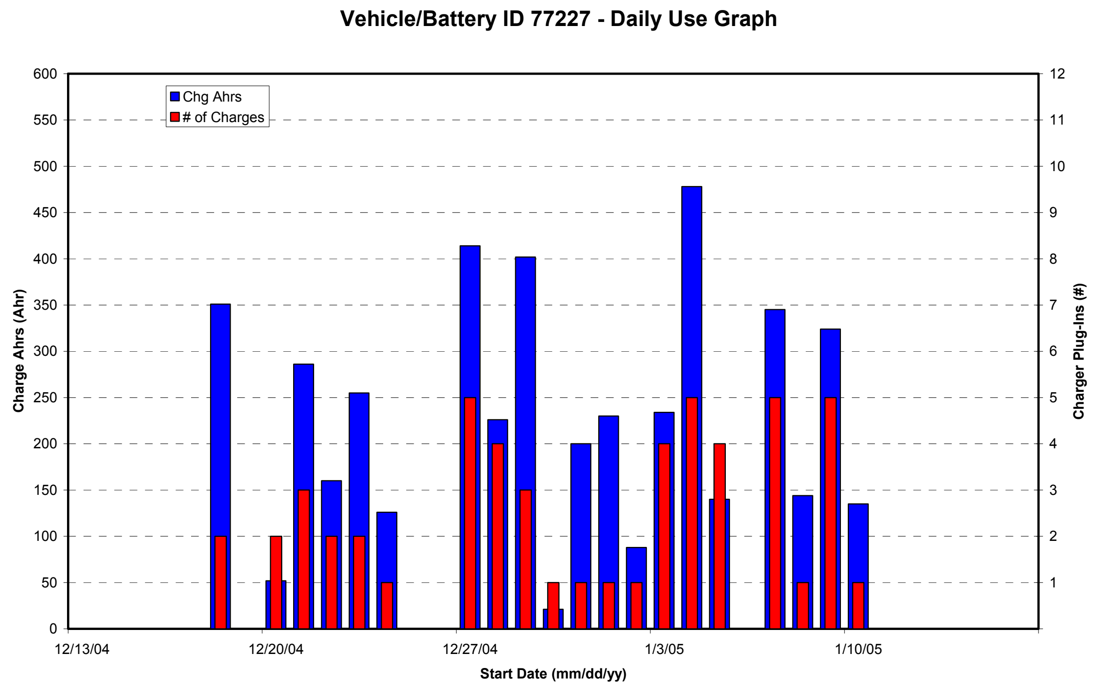

Figure 3-4
Number of charges and Ahrs delivered for Vehicle 17227, 12/13/04 – 1/10/05

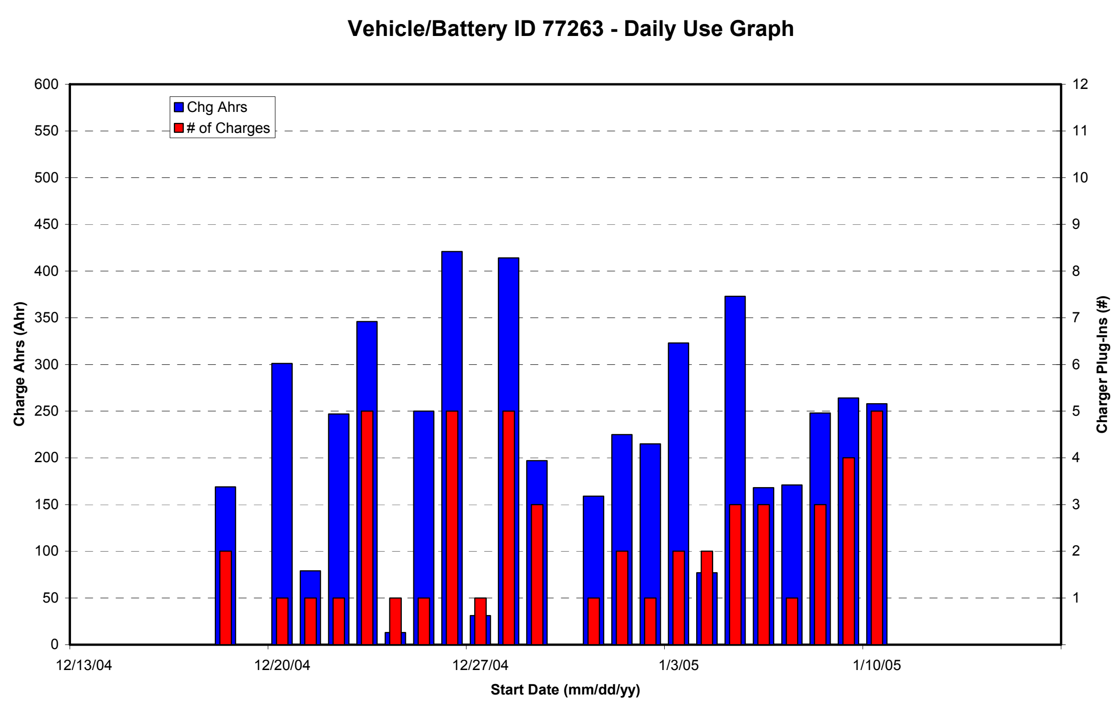

Figure 3-5
Number of charges and Ahrs delivered for Vehicle 17263, 12/13/04 – 1/10/05

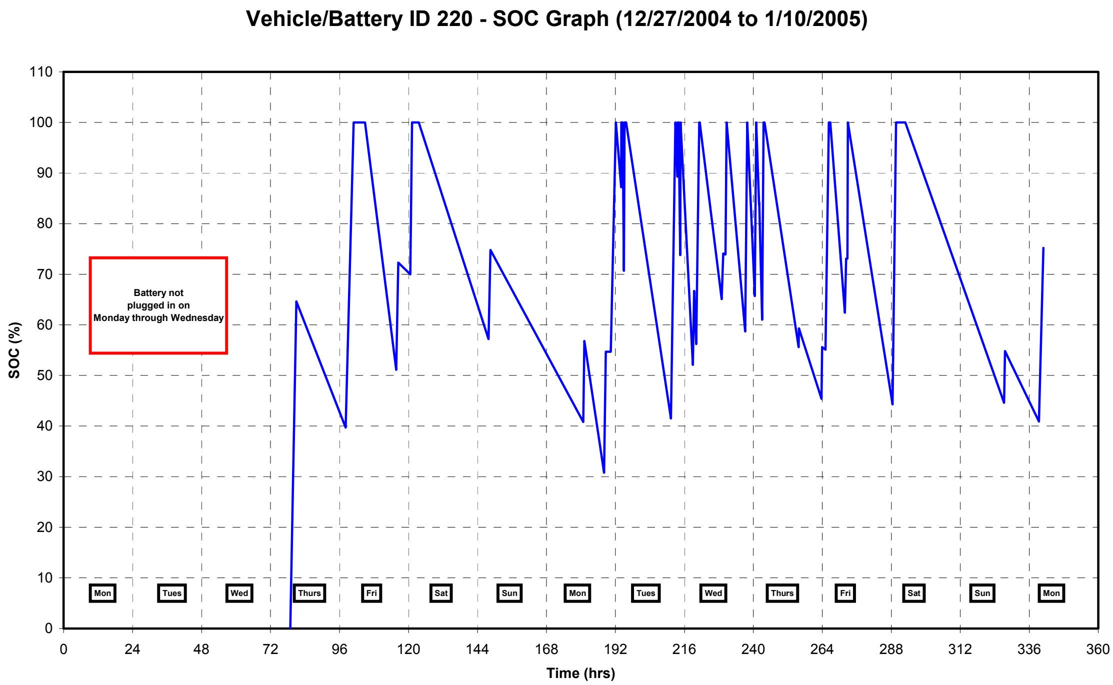

Figure 3-6
Vehicle 220 State-of-charge, 12/27/04 – 1/10/05

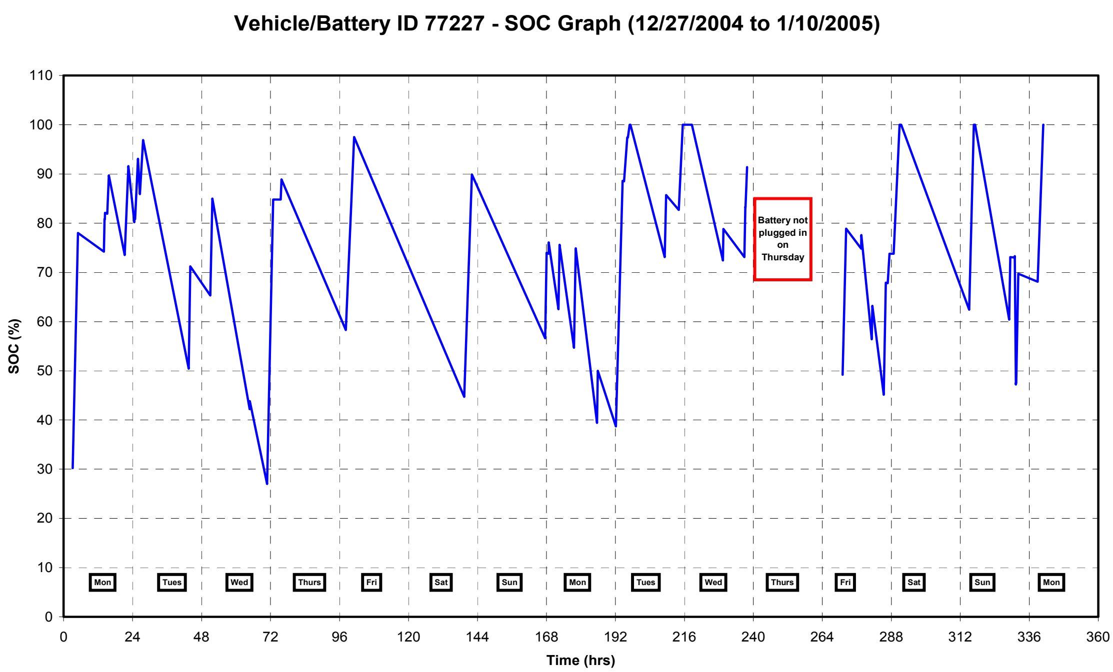

Figure 3-7
Vehicle 77227 State-of-charge, 12/27/04 – 1/10/05

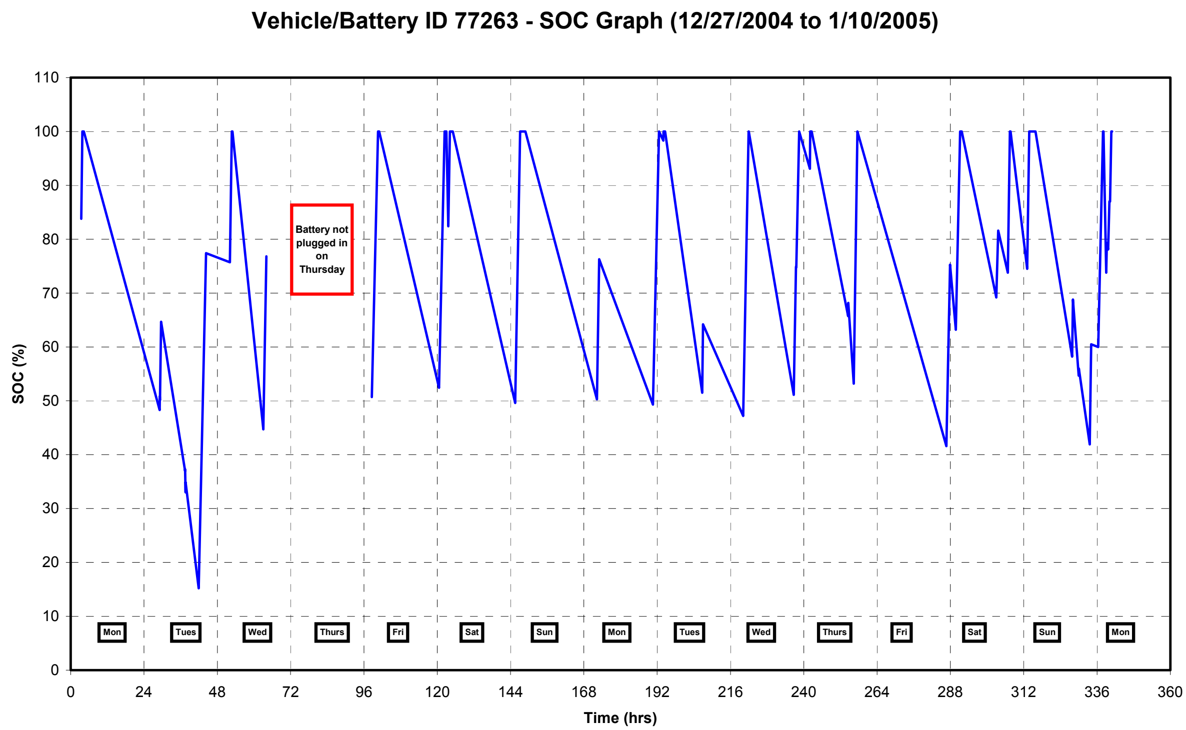

Figure 3-8
Vehicle 77263 State-of-charge, 12/27/04 – 1/10/05

Table 3-2
Charge History Summary 2/12/05 – 3/05/05

Batt ID	Batt Cap	Charge Ahr	Days	Total Charge Time	Avg Batt Temp	Max Temp	Min SOC	Avg Initial SOC	EQ Events	Fast Charge Events	Avg Daily Use	Avg Daily Charge Time	EBUs
220	500	3081	19	29:51:02	92.5	147	32.6	69.5	0	46	189.2	1.83	0.5
57024	340	527	16	8:06:32	64.1	86	1.6	66.2	0	15	38.4	0.59	0.1
57025	340	10	8	0:45:02	61.6	66	46.5	64.6	0	7	1.5	0.11	0.0
77202	500	2576	18	35:09:46	101.8	129	20.8	77.3	0	45	167.0	2.28	0.4
77222	500	3036	17	30:21:28	85.6	111	18.8	63.4	1	45	208.4	2.08	0.5
77226	500	3729	19	32:32:20	81.6	118	34.7	68.4	1	40	229.0	2.00	0.6
77227	500	1350	18	15:17:53	77.8	105	36.1	81.0	0	21	87.5	0.99	0.2
77258	500	3297	19	28:22:35	83.7	109	7.1	53.7	1	42	202.4	1.74	0.5
77260	500	2064	19	18:20:51	78.6	100	20.2	57.2	0	16	126.7	1.13	0.3
77263	500	2598	19	24:48:25	86.4	114	22.7	65.9	0	27	159.5	1.52	0.4

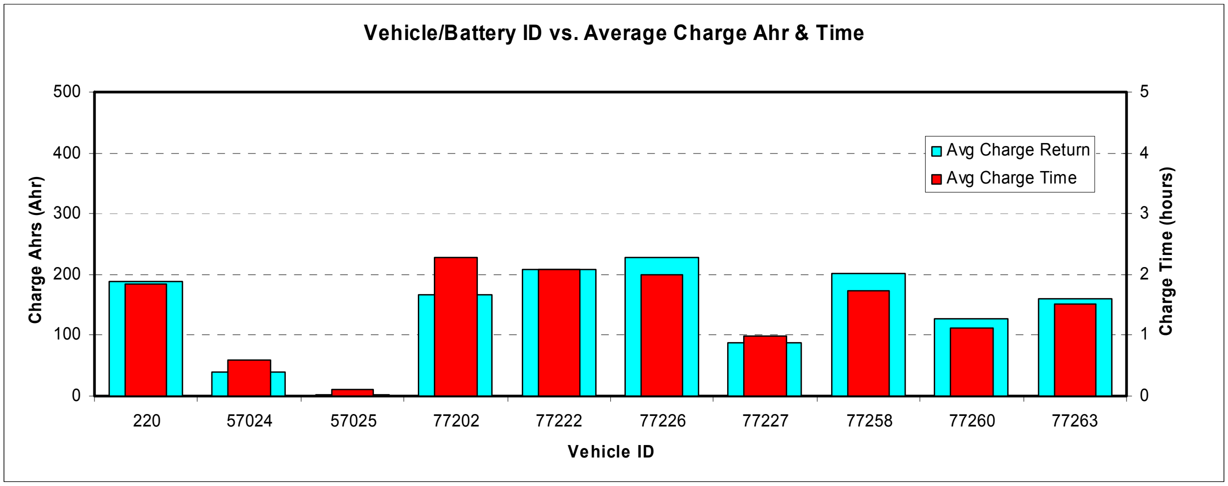

Figure 3-9
Average charge returned and charge time, by vehicle, 2/12/05 – 3/05/05

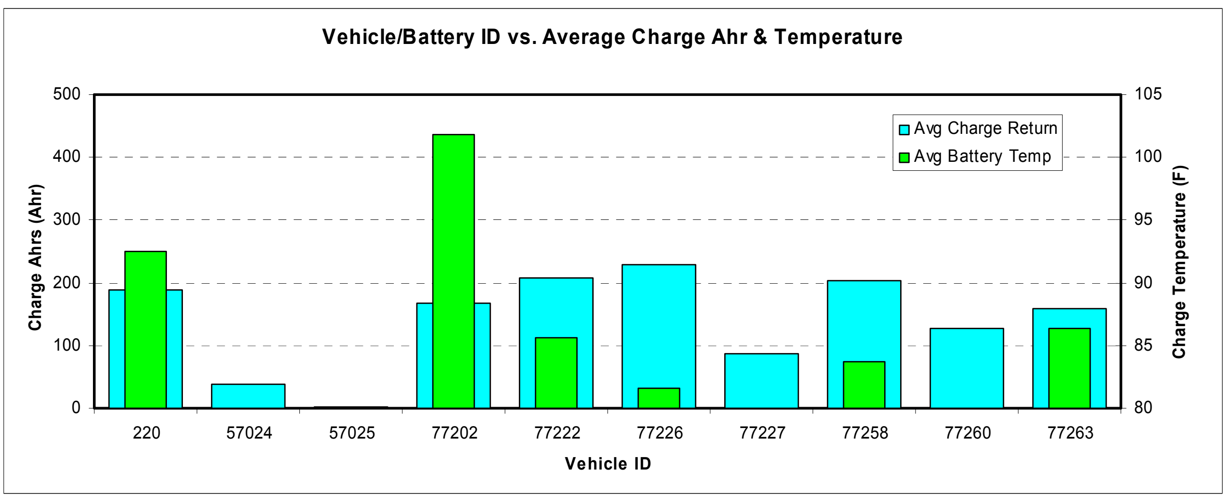

Figure 3-10
Average charge Ahr and battery temperature, all vehicles, 2/12/05 – 3/5/05

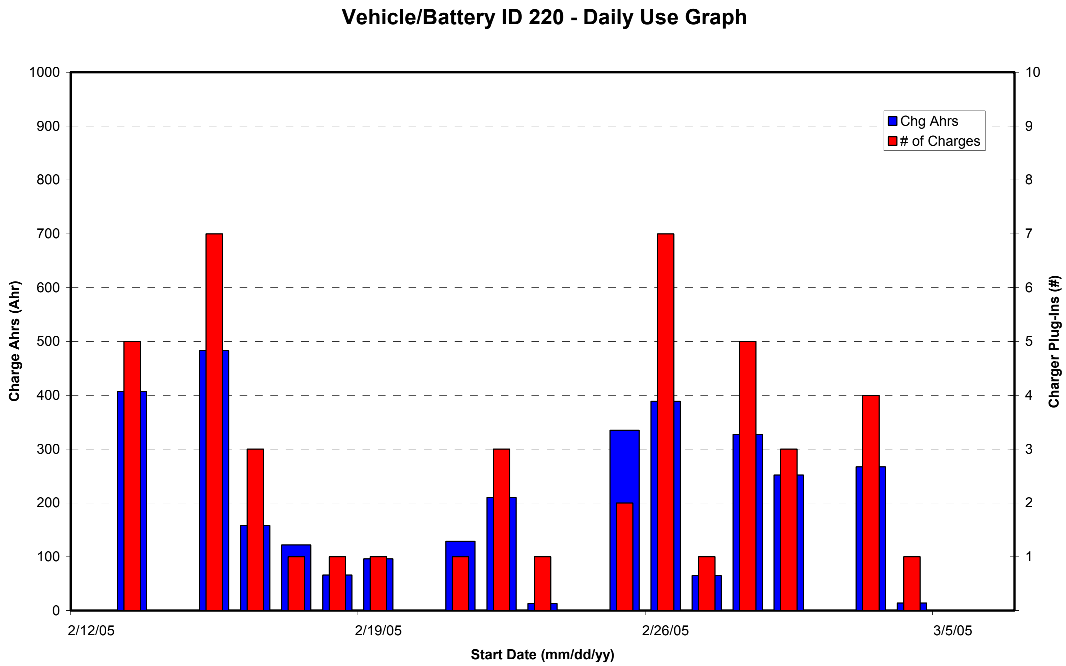

Figure 3-11
Number of charges and Ahrs delivered for Vehicle 220, 2/12/05 – 3/5/05

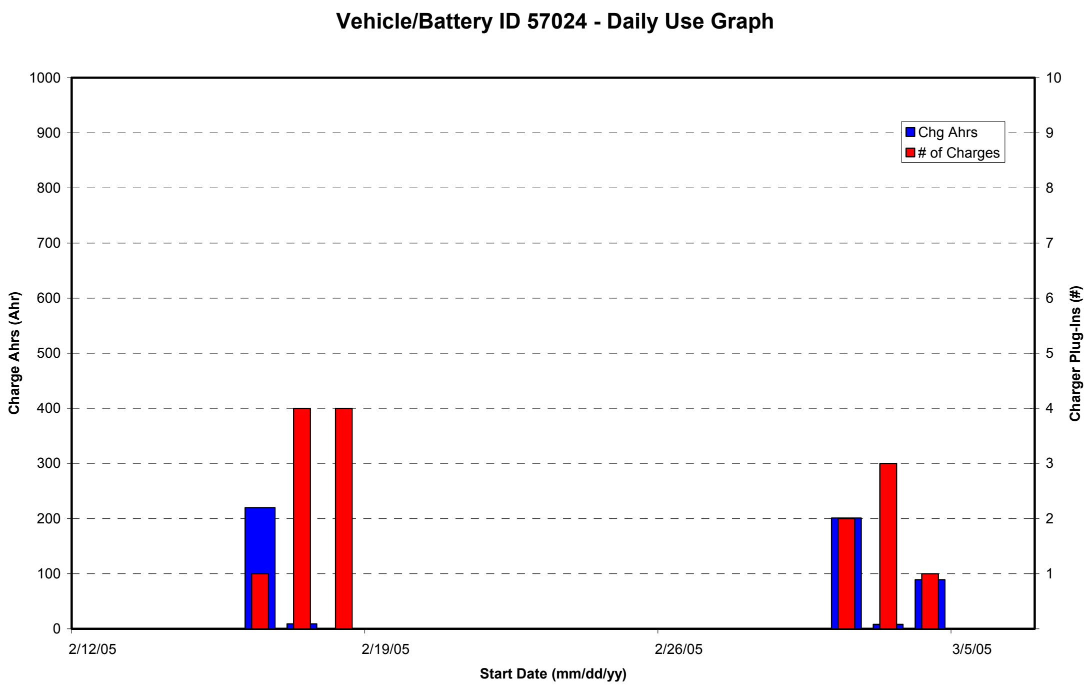

Figure 3-12
Number of charges and Ahrs delivered for Vehicle 57024, 2/12/05 – 3/5/05

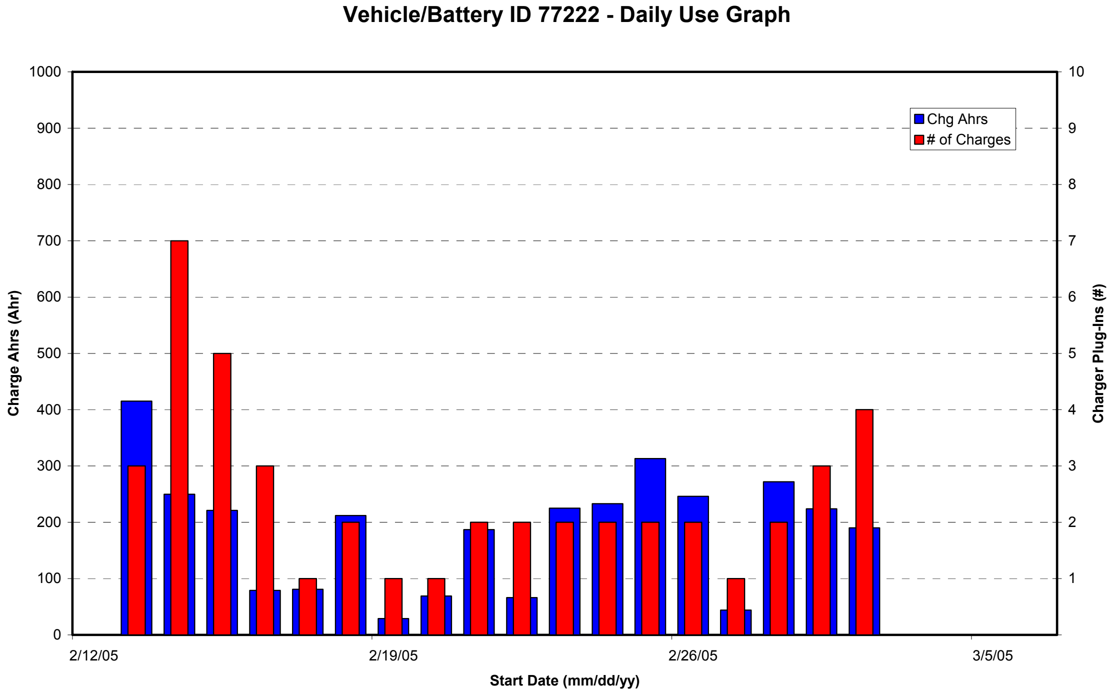

Figure 3-13
Number of charges and Ahrs delivered for Vehicle 77222, 2/12/05 – 3/5/05

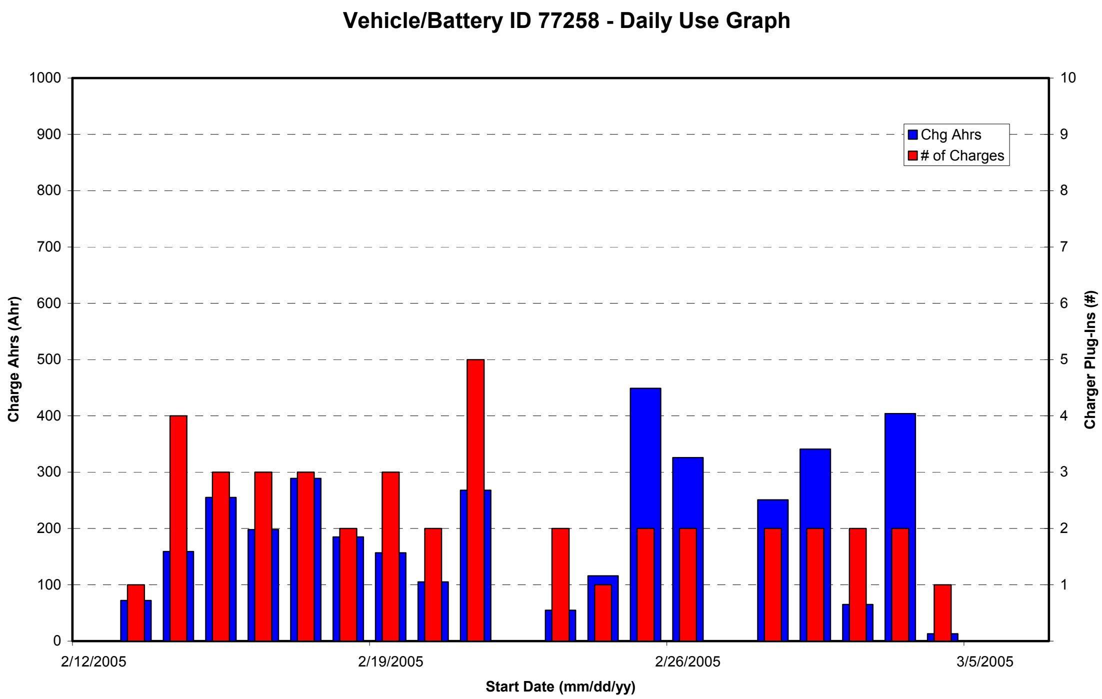

Figure 3-14
Number of charges and Ahrs delivered for Vehicle 77258, 2/12/05 – 3/5/05

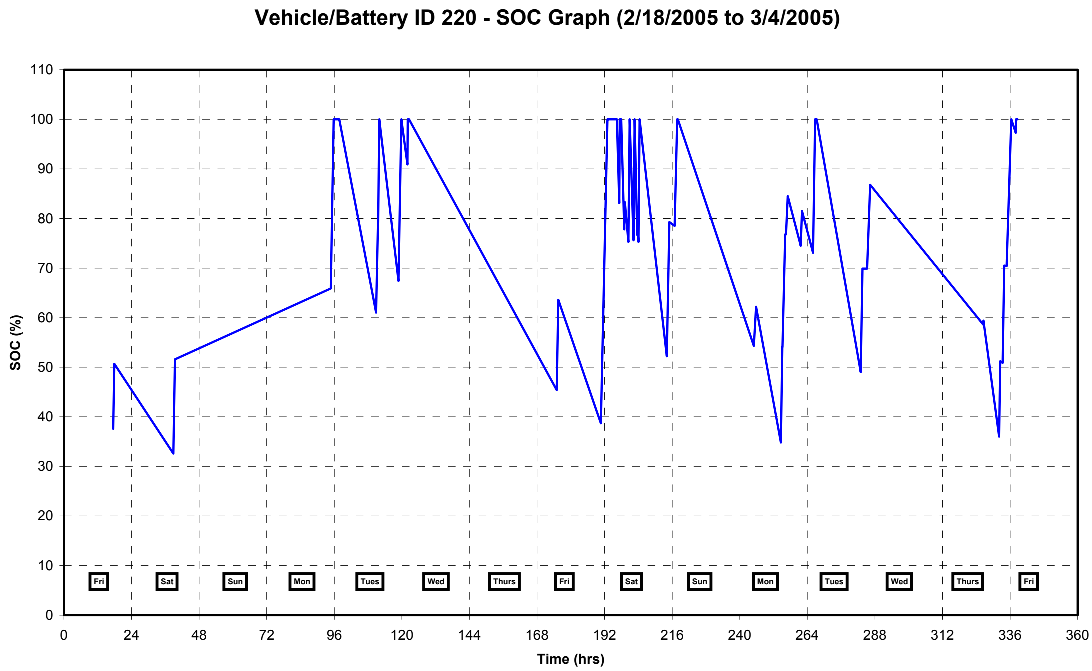

Figure 3-15
Vehicle 220 state-of-charge, 2/18/05 – 3/4/05

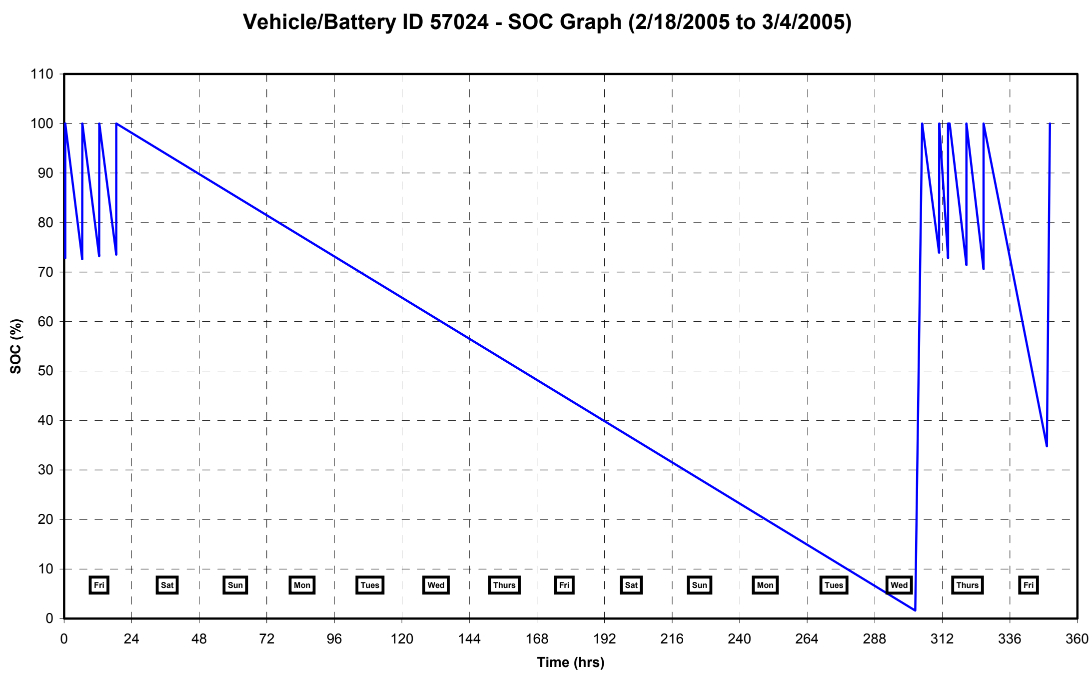

Figure 3-16
Vehicle 57024 state-of-charge, 2/18/05 – 3/4/05

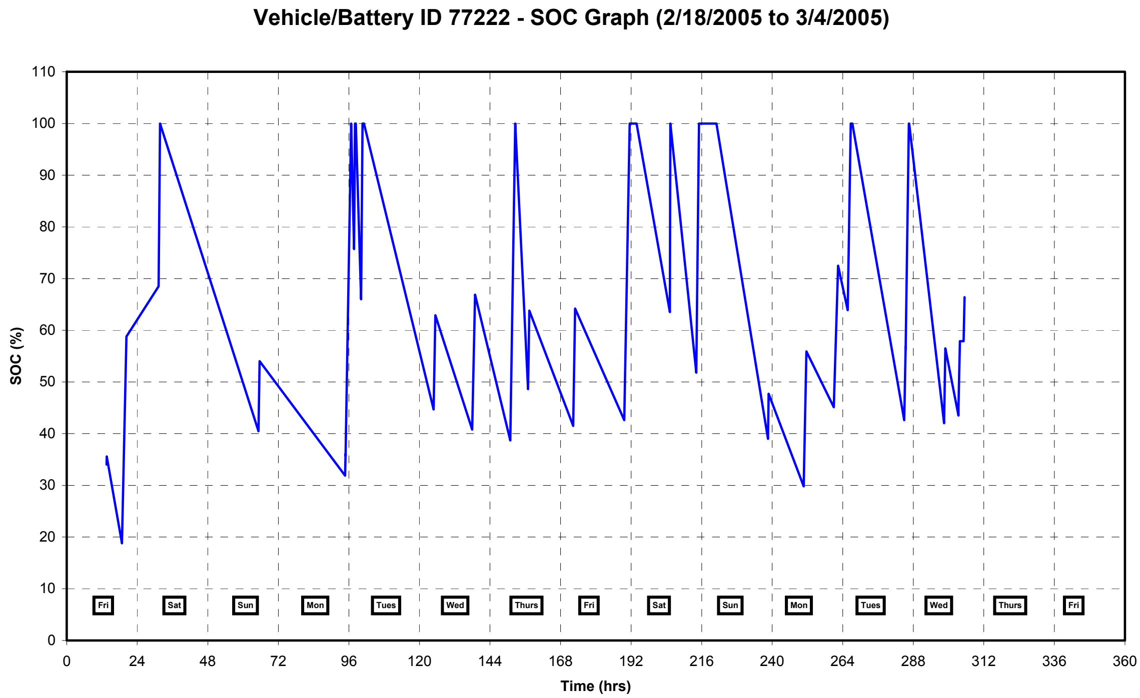

Figure 3-17
Vehicle 77222 state-of-charge, 2/18/05 – 3/4/05

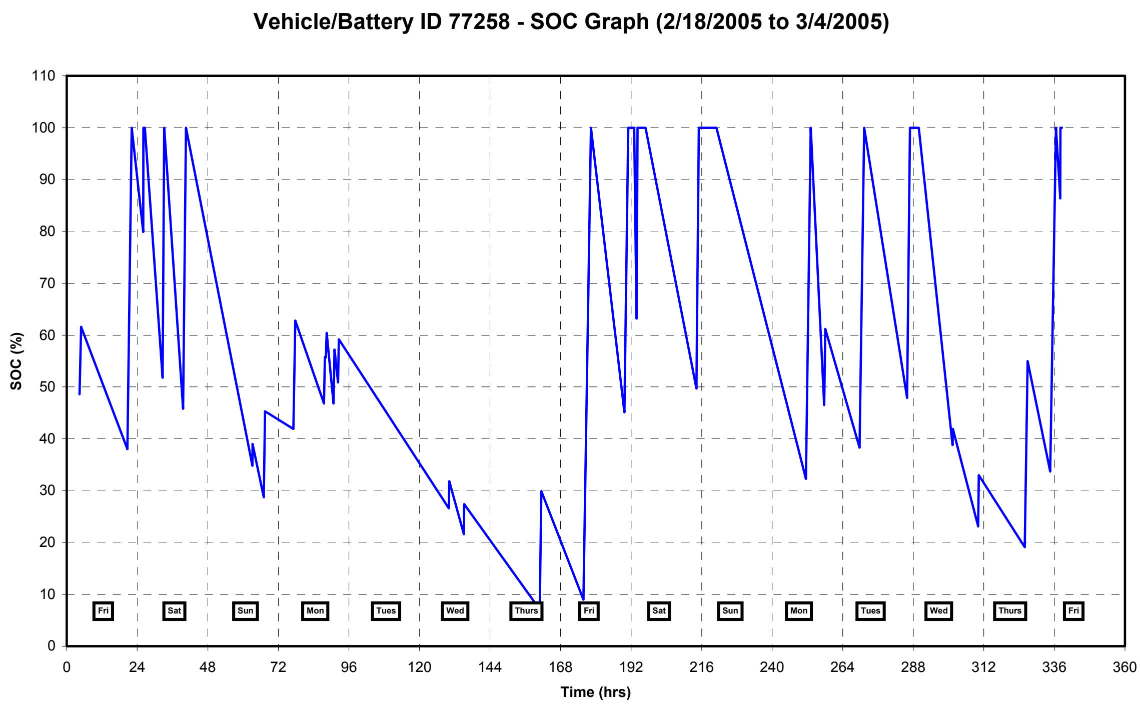

Figure 3-18
Vehicle 57024 state-of-charge, 2/18/05 – 3/4/05

Vehicle Usage Analysis and Discussion

The equivalent battery usage (EBU) data shows that none of the vehicles were used to their full capacity. The EBU data is particularly useful in analyzing the vehicle usage scenarios or applications that could benefit most from fast charging. Throughout this demonstration, vehicle usage was not significant enough to demand a fast charging regime.

For example, the two beltloaders, vehicles 57024 and 57025, recorded very low EBUs. Figures 3-12 and 3-16, respectively, show that Vehicle 57024 was not charged for 10 days. These findings were not surprising, however, because beltloaders typically operate for up to seven days between charges. While they are not a prime candidate for fast charging, they are very much a prime candidate for electrification.

The highest EBU recorded during the first sample period was vehicle 77202, with an EBU of 0.8, and during the second sample period was vehicle 77226 with an EBU of 0.6. Even these EBUs demonstrate relatively low usage for baggage tugs.

One reason for the low vehicle usage is the location of this demonstration; the T Concourse is the closest concourse to the baggage claim, so these baggage tugs had less distance to travel. Were these vehicles and this demonstration located at the E Concourse, which is farthest from the baggage claim, the EBU numbers would be much higher, and the need for fast charging more compelling. The average bag tug with a new battery, fully charged, can travel approximately 26 miles on a charge.

The purpose of this demonstration, however, was not to demonstrate the need for fast charging but to demonstrate the power-sharing feasibility with a passenger loading bridge.

The usage figures raise other questions worthy of discussion.

Q: Does it mean that Delta could reduce the number of vehicles operating at this gate, given their low usage?

A: No, because a certain number of vehicles are needed to efficiently handle the volume of baggage and cargo coming off of any given plane in a prescribed timeframe.

Q: Does it mean the vehicles could operate with smaller, lower capacity (and therefore less expensive) batteries?

A: Theoretically, yes, however, batteries add weight to vehicles and, for baggage tugs, weight is a benefit because the vehicle counterbalances the cart full of baggage. Also, a smaller capacity battery in a vehicle working a gate located farther from baggage claim would be insufficient to do the job. In addition, the greater battery capacity may be necessary when another vehicle is out of service, increasing the daily workload on the remaining vehicles.

Energy Usage

To demonstrate that power could be shared without conflict by the Jetway and the fast-charger, the team monitored the current and all power usage at Busway A, at the main feed into Switchboard 2DSA, the feed out to Jetway 7, and on the charger disconnect switch mounted on the Jetway at the apron level.

Power was monitored from December 10, 2004 through February 17, 2005 in 30-minute samples. On February 18, 2005, the team switched to one-minute samples. Analysis of the data collected at the Jetway and the charger monitors between February 20 and 23 demonstrated that the charger disconnect was working.

Effect on Breaker

Figure 3-19 shows measurements of every single cycle maximum, minimum and average, at Jetway 7. Instances where maximum current across all three phases exceeded the 100-amp rating of the circuit are short duration transients from the Jetway motor inrush. These peaks were not associated with the charger current, and would have occurred regardless of the existence of the charger.

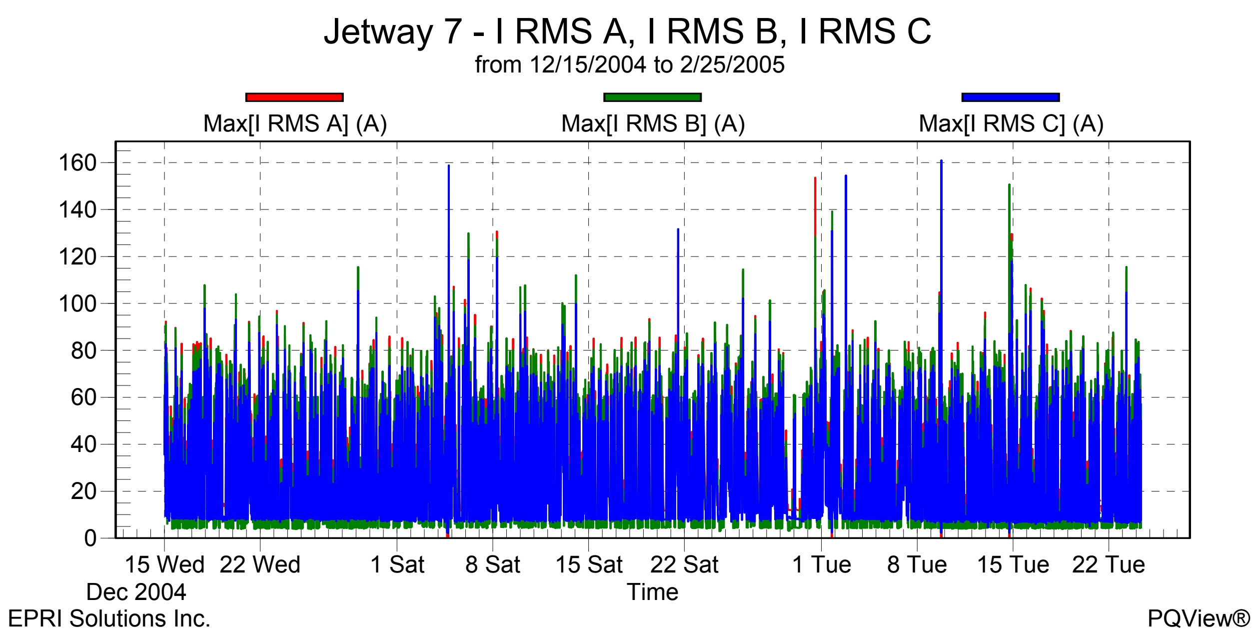

Figure 3-19
Single cycle maximum current, Jetway 7

Figure 3-20, which shows monitor readings of average current on the breaker at Jetway 7, offers a more realistic view of the effect on the breaker. This graph shows that at no time was power demand in excess of the breaker's 100-amp capability.

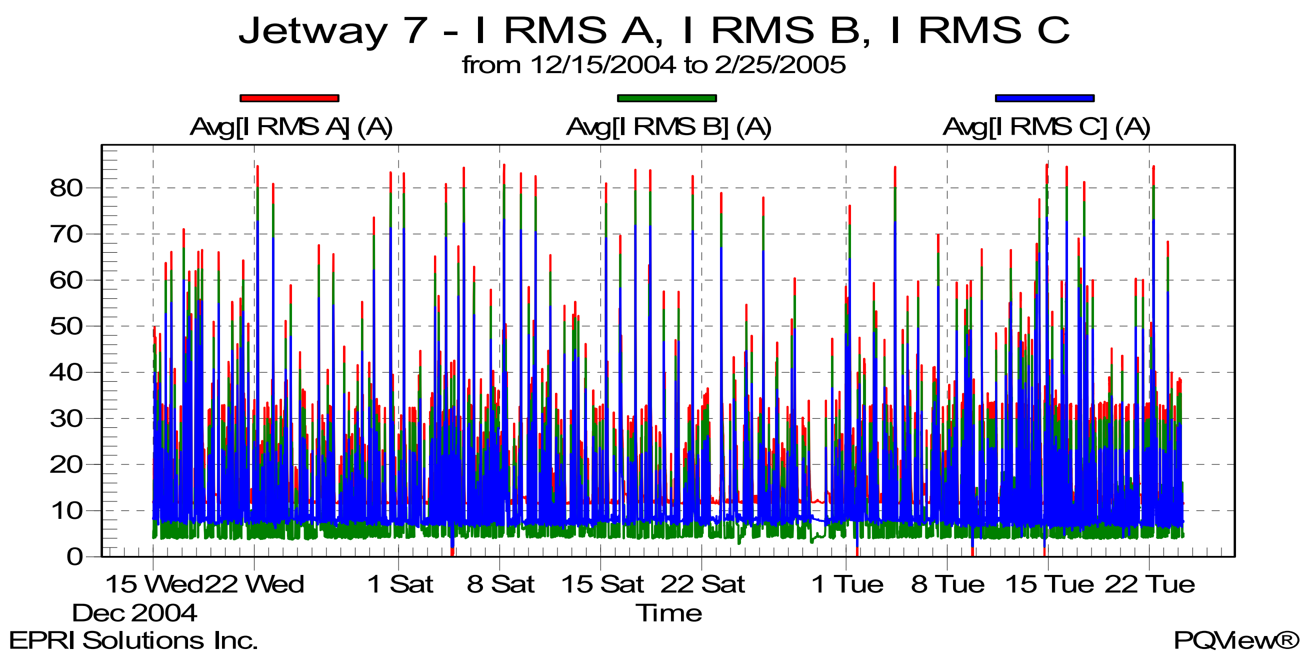

Figure 3-20
Average current, Jetway 7

Effect on Switchboard

The capacity of switchboard 2DSA, which provides power to Jetways 5 and 7, as well as other internal terminal facilities, is 600 A.

Figure 3-21 shows the average current loading at Switchboard 2DSA, while figure 3-22 shows the average charger current during the period when data was manually downloaded from the charger. The charger has very little impact on the peak circuit loading. Even if the 85-amp peak average charger current were added to the 100-amp peak average switchboard current, the total load of 185-amp would be well within the 600-amp rating of the switchboard main breaker.

The data show that even an additional charger could be added to the circuit with little impact on the switchboard main breaker.

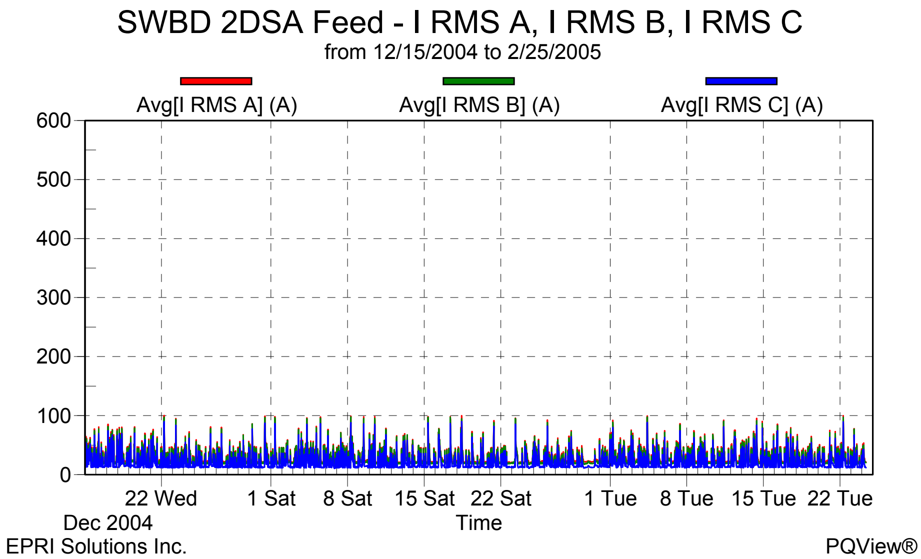

Figure 3-21
Average current loading of Switchboard 2DSA is well below 600-amp breaker rating

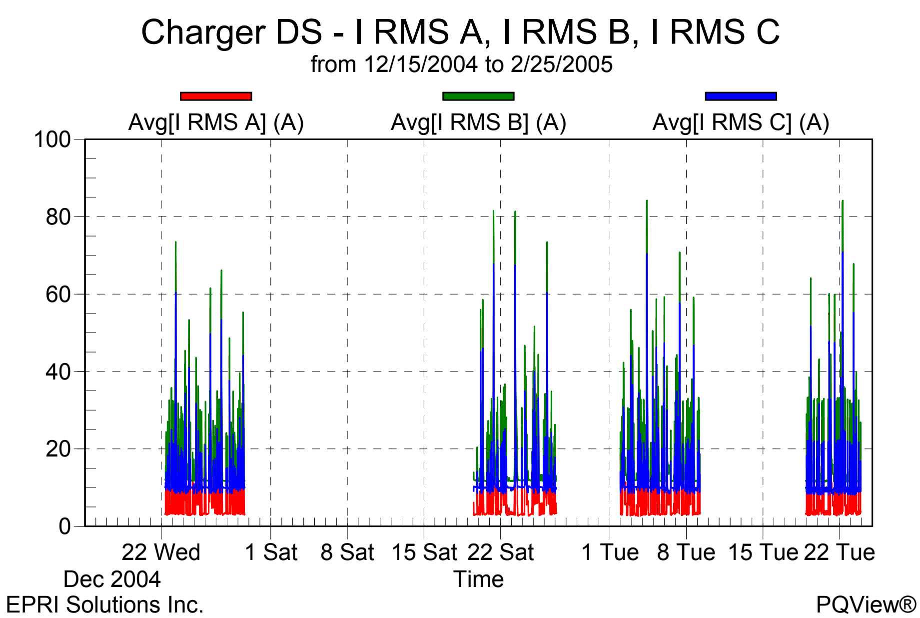

Figure 3-22
Average charger current loading

Effect on Busway

The capacity of the busway is 1,600-amp. The busway supplies power to six switchboards, including three Jetway feeders. The impact of multiple chargers on busway peak loading will be negligible as shown in figure 3-23.

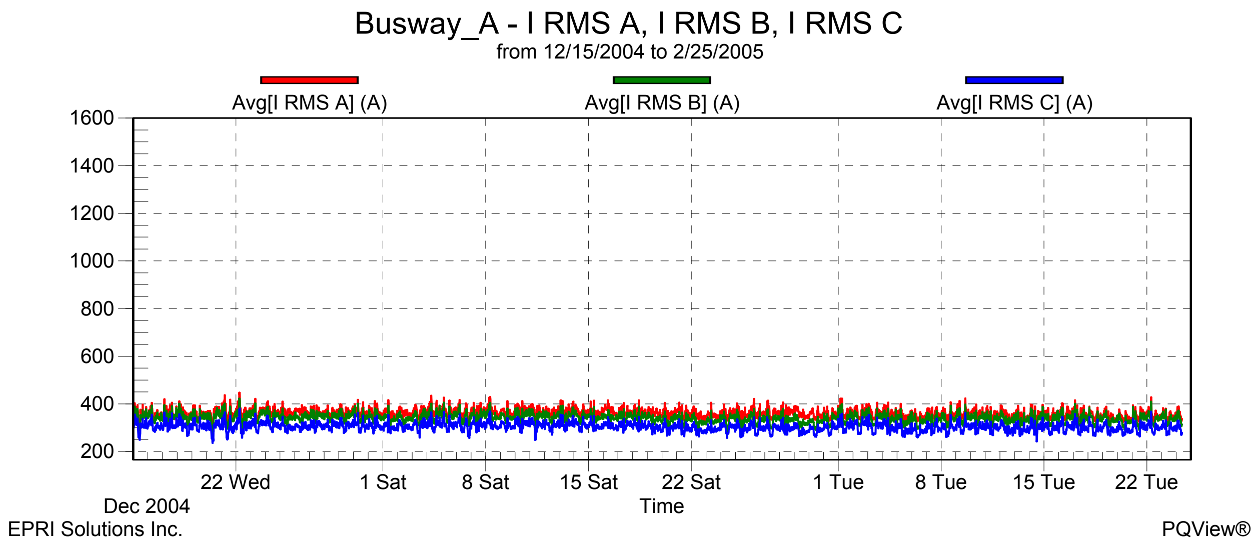

Figure 3-23
Effects of fast charging on busway capacity

Given the significant headroom that exists on the busway breaker, the team projected the potential impact of three 60 kW fast charging systems on busway loading. Their findings are summarized in Table 3-3. Charger diversity is a measure of how many chargers are on at the same time. Diversity of 100% means no chargers are charging, while 0% diversity means all three chargers are charging at full capacity. The purpose of the projection is to show the maximum potential kVA demand and the impact on the percent of usable busway capacity as the charger load increases.

For example, when no chargers are in use (100% diversity), the 292 kVA demand on the circuit represents 22% of the circuit's maximum capacity. At 50% diversity, meaning half of the chargers potential demand in use, their 389 kVA demand on the circuit represents 29% of the circuit's maximum capacity. At 0% diversity, meaning all the chargers are in full use, drawing maximum power, they are consuming 36% of the circuit capacity.

It should be noted that new fast charging systems are 80 kW and would require updated values in this analysis. Even with the higher power ratings of the new chargers, diversity and capacity numbers would increase accordingly, however, the usage would still be below 50%. Because the chargers cut off when the other primary loads – the Jetways – are in operation, peak loading would not change, although there would be an overall increase in energy consumption.

Table 3-3
Summary of effects of fast charging on busway

Assumptions							
Jetway Charger Count	3						
Average per charger kVA demand	64						
Average per charger KWh/30 days	4,624						
Charger Diversity	100%	50%	40%	30%	20%	10%	0%
Usable Capacity kVA	1,330						
Recorded Data							
Maximum Demand kVA	292						
Maximum % Usable Capacity	22%						
Projected kWh/30 days	148,835						
Projections							
Maximum projected demand kVA	292	389	408	427	446	466	485
Projected maximum% usable capacity	22%	29%	31%	32%	34%	35%	36%
Projected kWh/30 days	162,706						

Effect on Transformer

The main transformer for this section of Concourse T serves the three Jetways from Busway A, plus four other Jetways. When data was recorded last summer for the initial feasibility report, the transformer was operating at 46% capacity. With the new data gathered during this second phase of the project, projected over 30 days with all chargers charging at full power (0% diversity), the transformer is operating at 57% capacity, as shown in Table 3-4.

Table 3-4
Summary of Effects of Fast Charging on Transformer

Assumptions							
Jetway Charger Count	7						
Average per charger kVA demand	64						
Average per charger kWh/30 days	4,624						
Charger Diversity	100%	50%	40%	30%	20%	10%	0%
Usable Capacity kVA	4,000						
Recorded Data							
Maximum Demand kVA	1,820.45						
Maximum % Usable Capacity	46%						
Projected kWh/30 days	794,612						
Projections							
Maximum projected demand kVA	1820.45	2046	2091	2136	2181	2226	2271
Projected maximum% usable capacity	46%	51%	52%	53%	55%	56%	57%
Projected kWh/30 days	826,983						

Energy Use Analysis and Discussion

The projected load on the transformer, 57% could pose problems for the system. Many airports are designed for redundancy in the event of a transformer failure or other emergency; the systems are designed so that any one transformer is not operating at a capacity greater than 50% in order to allow it to handle an additional transformer's load, in the rare circumstances of a transformer failure.

The findings show an opportunity for load shedding. A future recommendation may be to develop a contingency algorithm that sends a signal to shut down the chargers in the event of a power emergency such as a transformer failure.

Gate T7 is a wide-body gate; the size of the aircraft that use the gate demand 10 vehicles to be available to serve the aircraft. Other gates, such as those on the A and B concourses at Atlanta, serve narrow-body aircraft, and typically demand about half of the service vehicles per gate. At these gates, Delta would likely install a fast charging system at every other gate instead of at every gate, so the power requirements (in addition to the number of chargers) would drop accordingly.

Team members note that increased equipment usage consistent with loading of heavy cargo, for example, or adding pushback tractors to the vehicle profile, would result in increased kVA demand.

While there appears to be plenty of headroom at this location, at this airport, in this demonstration, other airports will be different, and a careful analysis of available capacity will be necessary.

To determine the average energy usage for each type of equipment over a 30-day period, EPRI Solutions combined the charger summary data presented in Table 3-1 with the kWh usage per 30 days presented in Table 3.3. It was determined that the average beltloader consumes 65.427 kWh in 30 days. The average baggage tractor consumes 561.699 kWh over 30 days as shown in Table 3-5. These projections can help a utility determine the potential load from a fast charging project similar to this demonstration.

Table 3-5
Summary of Energy Usage from Data Collected; Projected over 30 days

Equipment Description	Battery ID	Charge Ahr	Days	Charge Ahr/Day	Charge Ahr/Day % of Total	Projected kWh/Day	Projected kWh/30 Days
Belt Loader	57024	527	16	32.938	2.73	4.202	126.070
Belt Loader	57025	10	8	1.250	.10	0.159	4.784
Baggage Tractor	220	3081	19	162.158	13.42	20.689	620.666
Baggage Tractor	77202	2576	18	143.111	11.84	18.259	547.763
Baggage Tractor	77222	3036	17	178.588	14.78	22.785	683.553
Baggage Tractor	77226	3729	19	196.263	16.24	25.040	751.205
Baggage Tractor	77227	1350	18	75.000	6.21	9.569	287.065
Baggage Tractor	77258	3297	19	173.526	14.36	22.139	664.179
Baggage Tractor	77260	2064	19	108.632	8.99	13.860	415.792
Baggage Tractor	77263	2598	19	136.737	11.32	17.446	523.366
			TOTAL:	**1,208.203**	**100**	**154.148**	**4,624.442**
Average kWh per belt loader projected over 30 days:							**65.426**
Average kWh per baggage tractor projected over 30 days:							**561.699**

4

FINANCIAL ANALYSIS

The findings of this demonstration provide a foundation for determining the financial feasibility of widespread installation of fast-charging at an airport such as Atlanta Hartsfield International.

Project Budget

The project budget underwent many changes as activities progressed. The budget in Table 4-1 represents an original estimate of the hard costs of the project.

Table 4-1
Original estimated project budget

Task	Estimated Cost
Acquisition of 10-port rapid charging system	$112,500
Rapid charging system power sharing option	$1,775
Acquisition of bridge power sharing switch gear	$3,500
Installation of bridge power sharing switch gear	$1,000
Installation of rapid charging system	$11,800
Support and monitoring during operation	$10,000
Reporting	$2,000
Electric GSE vehicles provided by airline	N/C
PROJECT TOTAL	**$142,475**

Budget Deviations

The biggest deviation from this initial budget was in installation cost. Budgeted originally at $11,800 then revised to approximately $15,000, actual costs totaled $31,848. Labor totaled $20,053 and materials totaled $11,795. A breakdown of installation costs is available in Appendix A.

Among the unbudgeted costs was a line-item for pre-installation, most of which involved the need for contractor security clearance, a $3,422 expense that was never anticipated when this project was initially envisioned prior to September 11, 2001.

Although the installation cost doubled the budget, it likely was lower than it would be in other markets, where installation can cost as much as $100,000 – $150,000.

This project benefited significantly from experience that Georgia Power and its contractor, Cleveland Electric gained in an earlier fast charging installation at Emory University. The Emory project provided insight that led to more efficient work at this site. The need for thick, flexible insulated cable to accommodate the high DC current and conduit sufficient in size to house the large cable, together with the distance of the cabling and conduit, all contribute to increased installation costs. In this case, the experience from the Emory installation enabled project managers to anticipate and plan for their needs. Still, the costs were considerably higher than originally budgeted.

Installation costs in any project will vary by market, especially given varying labor rates. Participants estimate this installation was approximately half of what it might have been in other markets, because the labor rate for this project is low; Georgia Power's contract with Cleveland Electric, at $46 per hour, is well below market in Atlanta – and probably most cities.

Considerations and Discussion

Conventional Charging vs. Fast Charging

To compare the cost of conventional charging to fast charging, factors such as equipment purchase price, installation, and application must be considered.

The purchase price of a 10-port fast charging unit is approximately $112,000 – $125,000.While a single conventional charging unit costs $10,000 – $15,000, the cost of purchasing 10 such units will be roughly equivalent to the cost of one multi-port fast-charging unit. This is not an "apples-to-apples" comparison, however, because numerous other factors affect system installation cost.

Factors such as power availability, physical location of the charging system, how much and how far conduit is needed, and whether concrete needs to be cut for burying cable, all contribute to costs of both fast charging and conventional charging installations. Many of the complex and expensive tasks, such as cutting concrete, could be necessary in either a conventional charging installation or a fast charging installation. However, running 10 lines of conduit to serve 10 conventional chargers, for example, can be more expensive and complex than running one line of conduit for five multi-port fast chargers. At the end of this demonstration participants estimated that the price of wire and conduit had increased by as much as 30% from when the project budget was created due to increases in the price of copper.

Project partner Cleveland Electric provided two installation estimates for a comparison. For five 50-amp service connections sufficient to serve 10 conventional chargers, the estimate was $17,800. For one 100-amp, 480-volt service connection, sufficient to serve one multi-port system with five dual-port chargers, the estimate was $11,200. (Appendix B). The estimates exclude variables such as concrete barriers or cutting. Because they do not include all the variables, it is difficult to specify exactly what one installation would cost versus another. Regardless, they demonstrate how the electrical installation costs can be lower for one multi-port fast charging unit than for multiple conventional charging units.

One of the most expensive and complicating factors in any dedicated infrastructure installation is power availability and accessible circuits. Power may not be available at all airports so the costs of supplying the needed power upgrades to serve multiple conventional chargers or higher power fast charging systems would need to be factored in to an overall cost analysis.

In addition to evaluating the hard costs and availability of power, a financial analysis must factor in whether the needs can be met by one or both systems. In Atlanta, as in many large airports with round-the-clock hub operations, conventional charging is insufficient to meet the duty requirements of the majority of the ground support equipment. Current conventional charging regimes, especially at gates in Atlanta's E Concourse, for example, are being pushed to the limits of the equipment's capacity, due to the 24-hour demand and greater traveling distance from the E Concourse to the baggage terminal. It is precisely because of this significant demand on equipment that Delta is considering fast charging to serve a large number of gates in Atlanta.

When conventional charging cannot meet an operation's duty cycle, the alternatives are fast charging or battery change-outs. Battery swapping is common in warehouse and factory applications, but not practical for airports. Therefore, for many airports, fast charging is becoming the best operational choice. Moreover, fast charging, even with the higher purchase price of a fast charger, is being shown to be more cost competitive than battery swapping, when all lifecycle costs are considered.

Dedicated Fast Charging Infrastructure vs. Jetway Power-Sharing

As discussed above, dedicated infrastructure for conventional or fast charging can be costly to install. This demonstration shows that power-sharing with a Jetway bridge not only is feasible, it may also be more cost-effective. For this demonstration, sufficient power was available on the Jetway bridge, eliminating the need for a dedicated circuit. In this application, it was more economical to use the bridge power-sharing approach.

Sharing power this way also is more efficient, since neither the charger nor the Jetway is in use for extended periods on an ongoing basis. Infrastructure dedicated solely to GSE chargers, then, can be viewed as an inefficiency that is avoided in a power-sharing arrangement.

How to quantify the value of power sharing? In cases where an airport simply does not have the available circuit for dedicated chargers, power sharing may provide a fast-charging option that was previously considered to be unavailable. One way to truly compare the costs of conventional charging vs. fast charging vs. fast charging with power-sharing would be to develop a per-plug cost that factors in the purchase cost of the equipment, all the related installation and infrastructure costs.

The U.S. Department of Energy currently is funding a broad-based effort involving multiple utilities, airlines and a fast charge manufacturer to create a model that will accept site-specific inputs and calculate the costs associated with different charging regimes at an individual site.

5

LESSONS LEARNED AND FUTURE OPPORTUNITIES

The demonstration team identified several lessons learned and observations for future similar power-sharing projects.

Installation

As noted in the previous chapter, the cost of installation was higher than was budgeted, but was likely less than it would be in many markets due to the utility's contract labor rate with the electrical contractor.

Factors affecting installation cost include the distance required to run the conduit and the size of the conduit. Heavier, 4-inch conduit is more expensive; the longer distance affects not just the materials cost but the labor cost, since heavier conduit is also more challenging and time-consuming for the electrician to work with.

The location of the charger and its components also affects installation costs; when existing building features such as walls or overhangs allow the units to be attached to their surfaces, it can result in lower costs than installing directly on the pavement. This demonstration installation, on the walls and overhangs, allowed the conduit to be hung rather than buried under the concrete surface. It also eliminated the need for bollards or other protective devices that would be necessary if the equipment were installed on the pavement.

Lesson #1: Parties should work together to identify installation locations that minimize the distance between the charger and its multiple ports, and that reduce the need for cutting concrete, installing bollards, etc.

Any business working within an airport setting faces significant challenges and potential headaches associated with obtaining the necessary security clearances.

Lesson #2: Consider working with contractors and businesses that have experience with airport operations and advance security clearance, if such an option exists, to minimize delays and save money.

Power Availability and Charger Choice

The power requirements for this demonstration were for 100-amp service. Newer, 80 kW fast chargers will require 125-amp systems or will need to be de-rated to draw 60 kW.

Lesson #3: The charger can be downsized to match the power availability by being configured with fewer ports or by being programmed to use less power in its operation.

Energy Monitoring

Three of the four energy monitors were connected to phone lines, enabling direct daily downloads of energy use data. The fourth monitor, installed on the charger disconnect switch, was out on the apron, where a phone line was unavailable. As a result, data downloads from this monitor were infrequent.

Lesson #4: A way to enable regular data downloads from this monitor would have improved the overall data-collection success of this demonstration. Future projects should devise a monitor.

The team would have liked to have been able to conduct short-term monitoring at a fast sample rate to capture the data on energy flow when the charger disconnect on the Jetway turned on, stopping power flow to the charger and redirecting it to the Jetway. The monitoring system did not allow the collection of high sample-rate data that would show exactly how the disconnect worked.

Lesson #5: Future tests of Jetway bridge power sharing should budget funds for a multi-channel data recorder, and additional installation and personnel costs that would be needed to accommodate such a test.

Jetway Operation

FMC Jetway representatives expected that the demonstration would be a success, given their previous experiences with power sharing of 400-Hz systems. Future installations of fast chargers on Jetways will need to consider potential implications of existing Jetway power-sharing arrangements with 400-Hz systems.

Lesson #6: If a Jetway already is sharing power with a 400-Hz system, adding a 90 kVA fast charging system, which requires 100-amp electrical service, may not be possible due to available power.

Sharing power with a 400-Hz system is feasible, but complications may occur because a 400-Hz system typically operates more frequently and for longer durations than a passenger loading bridge.

Lesson #7: If a charger is to share power with a 400-Hz system, it should be in an application that requires less charging time because power availability to the charger may be limited.

The disconnect signal was tied only into the bridge’s drive mode. Initially, there was some discussion about whether the disconnect signal also needed to be tied in to the bridge’s operation mode, which allows the bridge to be raised and lowered. The team determined that the bridge’s greatest power need was during the drive mode, and therefore decided to tie the disconnect switch only to the drive mode.

Lesson #8: Tying the disconnect switch to the bridge's operation mode could also be a problem, because gate attendants often leave the bridges in their "on" or operate position – even when they are not in use – barring the flow of power to the charger.

New PLC (programmable logic controller) bridge designs may be able to accommodate separate output controls, which would likely activate the power disconnect faster and more efficiently, since their signals are also capable of transmitting data.

Lesson #9: Instead of using a horizontal break relay plus a separate relay switch to the charger, in the future, FMC could connect an output signal from the PLC directly to the charger, eliminating the separate relay. Jetway could sell this as an option.

Charger Operation

The system in this demonstration was set up to equalize once a week on Sundays. The equalizations did not occur regularly; some equalization sessions were interrupted, and the charger data showed that some system equalizations were never completed. Because of the short duration of this demonstration, addressing this problem was not a priority.

Lesson #10: Future, longer demonstrations or permanent installations would require a system and operations review to determine when is the best time for equalizations. Factors to consider include the day of the week and time of day when vehicles are available.

Airport operations differ from warehouse operations where workers work consistent shifts with defined breaks. In an airport setting, workers take frequent breaks and spend a lot of time waiting for planes to come into the gate. Then, when they are working, they work at a very fast pace. Despite this difference, the attitude of equipment operators at an airport is similar to that of warehouse workers, and, as a result, the charger must be convenient to encourage employees to plug in.

Lesson #11: Chargers must be located close to the primary work site, since drivers will not go out of their way to charge their vehicles.

Energy Usage and Operations

Matching equipment with its application is one of the most important considerations for any operation using electric vehicles. While the vehicles in this demonstration were not heavily used and had duty cycles that did not require fast charging, many of the ground support vehicles operating at Atlanta Hartsfield do have demanding duty cycles that would benefit from fast-charging. Although developed to demonstrate power-sharing feasibility (not fast-charging feasibility), this project was also designed so that Delta could determine the viability of such an option in conjunction with fast charging at the gates and concourses in Atlanta that require a fast charging option.

Lesson #12: Vehicles in high demand applications are better candidates for fast charging; a power-sharing arrangement would be best considered for those gates that get higher usage.

For an airline to increase its use of fast charging, whether through dedicated infrastructure or through a power sharing arrangement such as in this demonstration, represents an increase in energy usage, potentially benefiting the utility. The local utility may benefit by working with the airlines to make the initial capital investment.

Power Requirements

This demonstration required 100-amp service. New 80-kW chargers will require 125-amp service. In facilities where the electrical service may not meet the higher current requirements of the new chargers, the charger can be down-rated to an appropriate size to match the power availability so that it only draws 60 kW and requires only a 100-amp circuit.

Lesson #13: New chargers with four and six ports that only draw 50 amps are being developed; such systems may be most practical in smaller cities with lighter loads. They may also be more compatible with arrangements where a passenger loading bridge is already sharing power with a 400-Hz system.

In situations where a full charging load coupled with other load on a transformer pushes it to operate at a peak that is above 50% of its capacity, airports may want to consider a load-shedding strategy.

Lesson #14: A future recommendation may be to develop an algorithm that allows a signal to be sent to the charger to shut it down automatically in the event of an emergency where a transformer exceeds 50% of its capacity. Currently the chargers require the Jetway to be completely off before charging is allowed. Another consideration would be to develop a charging algorithm that constantly monitors bridge power and adjusts charger output based on remaining available capacity. For instance if the Jetway requires 25% of the circuit capacity then the charger could use the remaining 75% of circuit capacity to keep on charging instead of shutting down to idle mode.

A
APPENDIX A

Following is a breakdown of project installation costs by activity.

Date	Hours	Labor Activity	Costs	Foreman	Journeyman	AP5	Service Van
		Hourly Rate by Classification		**$46.15**			**$7.50**
3/8/04	8	Phone calls to determine process to obtain airport access badges	$429.20	8			8
16/8/04	5	Airport meeting with Delta and Georgia Power	$268.25	5			5
20/8/04	6	Developed material list and unpacked server and power stations	$321.90	6			6
	19	**Invoice Number 029133 (23 November 2004)**	**$1,019.35**	**19**	**0**	**0**	**19**
		Hourly Rate by Classification		$46.59	$42.70	$33.67	$7.50
9/22/04	16	Fingerprinting and paper work for background check - Airport Access	$692.64	4	8	4	4
9/24/04	8	Fingerprinting and paper work for background check - Airport Access	$305.48		4	4	
9/29/04	40	Attend classes on airport security and driving	$1,726.88	8	24	8	8
9/30/04	8	Measurements for fabrication	$387.16	4	4		4
9/30/04	8	Cut unistrut and parts for installation	$305.48		4	4	
10/1/04	8	Received material at warehouse and prepared concrete pads at airport	$ 337.29	2	3	3	2
10/4/04	32	Delivered and set in place (3) power stations	$ 1,385.28	8	16	8	8
10/5/04	32	Deliver and mount server, begin installation of conduit	$1,385.28	8	16	8	8

Date	Hours	Labor Activity	Costs	Foreman	Journeyman	AP5	Service Van
10/6/04	32	Deliver and mount (2) power stations	$1,385.28	8	16	8	8
10/7/04	28	Run conduit to power stations	$1,168.92	4	16	8	4
10/8/04	24	Run conduit to power stations	$1,034.24	4	16	4	4
10/11/04	24	Run conduit to server and pulled feeder	$1,043.68	8	8	8	8
10/12/04	32	Pulled DC loop from server to (3) power stations	$1,385.28	8	16	8	8
10/13/04	29	Pulled DC loop from server to (2) power stations	$1,200.23	3	18	8	3
10/14/04	32	Pulled DC loop from server to (1) power stations and terminated wire	$1,385.28	8	16	8	8
10/15/04	30	Mount unistrut for cable support and terminated wire at (3) stations	$1,299.88	8	14	8	8
10/22/04	1	Discussion with AV about installation of I/O board in charger	$54.09	1			1
10/27/04	7	Terminate server AC and DC and communications	$378.63	7			7
10/28/04	3	Terminate AC line in J box on existing feed, power up and check operation	$162.27	3			3
	394	**Invoice Number 028979 (11 November 2004)**	**$17,023.27**	**96**	**199**	**99**	**96**
11/2/04	4	Start-up checks with Delta and AV , routed Belden cable to circuit board	$216.36	4			4
	4	**Invoice Number 029048 (16 November 2004)**	**$216.36**	**4**			**4**

Date	Hours	Labor Activity	Costs	Foreman	Journeyman	AP5	Service Van
11/8/04	16	Install unistrut cable supports and installed output cables from Delta	$762.08	8		8	16
11/9/04	16	Terminate CD and communication wires at stations and energize system	$762.08	8		8	16
	32	Invoice Number 029075 (22 November 2004)	$1,524.16	16		16	32
11/29/04	3	Moved communications cable and reconfigured software	$162.27	3			3
11/29/04	2	Replaced two broken cable supports (damaged by Delta)	$108.18	2			2
	5	**Invoice Number 030011 (24 January 2005)**	**$ 270.45**	**5**			**5**
	454	**Total Labor**	**$20,053.59**	**140**	**199**	**115**	**156**
		Materials	**$11,795.14**				
		Total Labor and Materials for Installation	**$31,848.73**				

B
APPENDIX B

The following are installation estimates for two different systems, provided by Cleveland Electric, for comparison.

Date 3-31-05

Don Francis
Georgia Power Co.

Atlanta, Georgia

RE: Delta Fast Charge disconnects for (5) 50a charging stations

Cleveland Estimate No.

Dear Mr. Francis,

We are pleased to provide the following pricing for furnishing and installation of the electrical work for the above referenced project. Pricing is based upon our interpretation of the site visit and specifications as you indicated.

Base Electrical Work……………………………………….. $ 17,400

We Have Included:

1. All applicable taxes, insurance and permits.
2. Transportation for our work force to and from the work site area.
3. Cleanup and moving of our trash.
4. Furnishing and installation of (5) 50amp disconnects to feed power stations.
5. Furnishing and installation of (5) 50amp breakers to feed new power stations.
6. Furnishing and installation of all special systems called for/to be provided for under Division 16.

We Have Excluded:

1. Formed concrete such as Housekeeping pads.
2. Participation in a general cleanup crew.
3. Any removal and/or handling of hazardous material.

We appreciate the opportunity to be considered to be part of your construction team. If you have any questions, please feel free to contact me at 404-505-4656.

Very Truly Yours,
CLEVELAND ELECTRIC COMPANY

Greg Ellington

Date 3-31-05

Don Francis
Georgia Power Co.

Atlanta, Georgia

RE: Delta Fast Charge 480v, 100amp disconnect

Cleveland Estimate No.

Dear Mr. Francis,

We are pleased to provide the following pricing for furnishing and installation of the electrical work for the above referenced project. Pricing is based upon our interpretation of the site visit and specifications as you indicated.

Base Electrical Work……………………………………….. $ 11,200

<u>We Have Included:</u>

1. All applicable taxes, insurance and permits.
2. Transportation for our work force to and from the work site area.
3. Cleanup and moving of our trash.
4. Furnishing and installation of (1) 480v, 100a disconnect to feed power server.
5. Furnishing and installation of (1) 480v, 100a breaker to feed new disconnect.
6. Furnishing and installation of all special systems called for/to be provided for under Division 16.

<u>We Have Excluded:</u>

1. Formed concrete such as Housekeeping pads.
2. Participation in a general cleanup crew.
3. Any removal and/or handling of hazardous material.

We appreciate the opportunity to be considered to be part of your construction team. If you have any questions, please feel free to contact me at 404-505-4656.

Very Truly Yours,
CLEVELAND ELECTRIC COMPANY

Greg Ellington

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