Creating A Self Sufficient Golf Cart

By

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Abstract

OFFICIAL ABSTRACT and CERTIFICATION

Creating a self sufficient solar golf cart

by Nick DePorzio, Katlyn Covney, Mat lee

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The purpose of our experiment is to test the feasibility of producing a self sustaining golf cart which operates using available ambient solar energy. If we apply known solar energy harvesting technology to fuel a golf cart, then we will be able to eradicate its dependence on city grid power supply by making it self-sustaining. A successful system would be implemented where golf carts are often used, on golf courses.

After formulating a hypothesis, we developed a method of testing it. We collected a _200 W solar panel, attached it to the battery circuit of the cart, in series, and monitored the electrical dynamics of the system. A problem was encountered. With the solar panel wired in series to the six batteries of the cart, charge was unequally distributed throughout the system, creating a delay in charge time and limiting overall run time. We hypothesized a solution to this problem, tested it, and found that wiring the solar panel in parallel to the six batteries created a more efficient system suited to our purpose. We continued to test and collect data on our original hypothesis using a parallel wired system.

After analyzing our data, we concluded that three of the 200W panels produced a surplus of wasted charge, and that one 200W panel produced an insufficient amount of charge to suit the purpose. Two 200W panels produced an optimal amount of charge to sustain normal activity indefinitely. Thus, the cart was successfully made self sufficient.

Category
Pick one only—mark an "X" in box at right

- ☐ Animal Sciences
- ☐ Behavioral and Social Science
- ☐ Biochemistry
- ☐ Cellular & Molecular Biology
- ☐ Chemistry
- ☐ Computer Science
- ☐ Earth Science
- ☑ Eng: Electrical & Mechanical
- ☐ Eng: Materials & Bioengineering
- ☐ Energy & Transportation
- ☐ Environmental Management
- ☐ Environmental Sciences
- ☐ Mathematical Sciences
- ☐ Medicine and Health
- ☐ Microbiology
- ☐ Plant Sciences
- ☐ Physics and Astronomy

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check ALL that apply):

   ☐ human subjects ☐ potentially hazardous biological agents

   ☐ vertebrate animals ☐ microorganisms ☐ rDNA ☐ tissue

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only ☐ Yes ☑ No

3. I/we worked or used equipment in a regulated research institution or industrial setting: ☐ Yes ☑ No

4. This project is a continuation of previous research. ☐ Yes ☑ No

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6. I/we hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work. ☑ Yes ☐ No

This stamp or embossed seal attests that this project is in compliance with all federal and state laws and regulations and that all appropriate reviews and approvals have been obtained including the final clearance by the Scientific Review Committee.

Research Plan

Research Plan

A. Question or Problem Being Addressed
   a. Can a 72V electric cart be fully rechargeable from totally solar powered panels?
B. Hypothesis/Engineering Goals
   a. Our hypothesis is that one battery via a single solar panel is able to charge all 6 batteries.
C. Methods/Procedures
   a. Methods
      - Discharging over a period of time
      - Recharging with 1 panel over 2 batteries
      - Recharging with 1 panel over 4 batteries
      - Recharging with 1 panel over 6 batteries
      - When charging less than 6, how long does it take to reach equilibrium?
   b. Procedures
      - Brainstormed
         1. How to construct the actual model
         2. Ideas of where to get our materials
         3. Ideas of what resources we have to us
      - Found various sources of information to allow a foundation of facts to launch our experiment
         1. Went through websites for ideas
         2. Decided on what information is helpful to our project
      - Obtained necessary equipment to conduct our research.
         1. Had a golf cart donated to us
         2. It included 12V batteries
         3. Used solar panels from storage
      - Attached solar panels to the golf cart.
         1. First using Wire for test purposes
         2. Later with a mounting system
      - Conducted several sets of runs in order to determine energy consumption and battery recharge time.
      - Concluded that it takes … to ...

D. Bibliography

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Research Report

Creating a self-sufficient golf cart

By Nick DePorzio, Katlyn Coveney and Mat Lee
Fountain Hills High School, Fountain Hills, AZ 85268

Research Question:

How can you keep a one-ton Global Electric Mobile (GEM) electric cart (G-4) cart off the grid and reduce the recharge time to a minimum?

Introduction:

Solar cars are a dream of the future. The ability to propel a solar cart with enough energy to transport a group of passengers may be a reasonable distance of 25 to 50 miles is still in the future. The true nature of creating a cart that is independent of the energy grid is here and now. We have an E 825 GEM cart that weighs about one ton. It has regenerative brakes and runs six recycle batteries totaling 72 volts of power.

Most carts are used for transportation in close proximity. Usually golf, recreation and local transport make this a viable test cart. Its 25MPH speed means it can be licensed for the open road in local traffic. The real challenge is to use the cart to its fullest and still keep the cart off the grid by reducing recharge time. This cart which is a one ton fully loaded four seat cart will be a good test of the theory we can keep electric carts off the grid. The ultimate question of how many panels is practical fir this application is the true question.

Hypothesis

Our hypothesis is that one solar panel is enough to power a solar cart for normal usage.

Methodology / Procedure:

(See Research Plan)

Works cited:

(See Research Plan)

Scope of Project:

1. Examine cart energy usage without solar panels.

2. Attach one to three panels to limited or all batteries

- Attach one panel to all six batteries
- Attach one panel to one batteries
- Attach one panel to two batteries.

- Attach two panels to two batteries
- Attach two panels to four batteries

- Attach three panels to three batteries

- Attach three panels to six batteries

3. Examine the equilibrium issue with limited batteries hooked up to the panels

4. Examine discharge and the range of vehicle.

5. Examine recharge with and without photo panels active.

6. Storage discharge of batteries in dark.

Equipment

Three photo panels donated from ASU that were 200 watt each (24 volt and 8 amps).

There were three 24 volt battery voltage regulators. They are PBR 24 Voltage regulators from ETA Engineering from Tempe Arizona. They act to protect the solar array as well as maintain voltage levels to the 24 voltage range with a maximum amperage of 9-18 amps.

Panels were wired on to the cart. Permanent aluminum structures will be bolted onto the cart to support the panels.

Voltmeters and ammeters were lab equipment that is available at the school.

Procedure:

Energy usage:

Test voltage at the batteries using a professional voltmeter and test amperage using a ring amp meter. The batteries will be tested at their terminals and the amperage will be tested at the series wires between batteries.

Panel charging:

Panels are hooked to a voltage regulator from a local company. The energy is regulated by the panels and are testable at these attachments. Both voltage and amperage will be tested at these points for each panel.

There are six batts; four under the rear seat and two in the front end all hooked in series. The regulators are hooked two in the rear on sets of two batts and one in the front end.

Hook up diagram configuration.

Insert here

Dark cycle testing in storage

The cart would be stored up to one week at a time to determine the energy loss in storage. The garage of the district was kept dark for virtually all the storage duration.

Vehicle range

The vehicle was tested with and without panels for short and long range journeys. The panels would be covered with black paper when no recharge was desired.

Cart Efficiency

The cart was weight approximated and run on a premeasured course. The energy used on average was monitored. Physics equations would be used to approximate the total energy used versus energy needed at a minimum.

Recharge rate findings

Recharge rate was examined by expending the cart energy down to 40% or lower and timing the rate to various recharge levels.

[A full recharge on the grid is about 7-8 hours from a low as 40%. A full recharge on three panels would be 3-4 hours at midday. (Up to three times longer at morning and late afternoon times.)}

Recharge is on a curve since you are pushing energy into set of storage batteries.

Battery Equilibrium

Several configurations of hooking up just one panel to one battery and two batteries were tried. The results demonstrated that the meter reading for the system was falsely higher until the batteries were allowed to come to equilibrium with the charged batteries. The resulting actual data was found to be reliable after a stopped period of 10 minutes.

Optimal hook up of the batteries was found to be one panel per two batteries. The best results were found to be six batteries hooked up to all three panels. The recharge was even for three matched panels on six matched batteries.

Data

Energy Consumption:

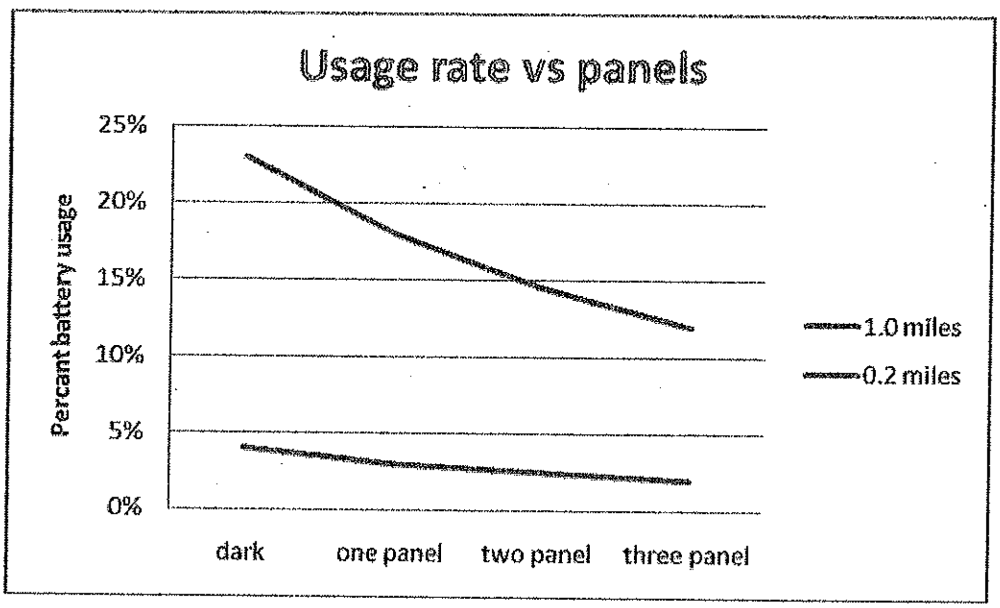
A. Short distance track

Flat test track:

Two flat tracks were mapped out. We did a few trials on quarter mile the track around the football field. The cart was run four times around the track for one mile. The cart was timed at an average of 3.5 minutes. The usage rate was 4-5% per quarter mile lap. This is consistent with the results on the long distance track to my house.

A 0.2 mile track was mapped out in the school parking lot that was also flat. The results were similar. With the panels covered the results were 3.5% on average for a 0.2 mile track or 4% average per quarter mile.

The panels were uncovered at mid day and the usage rate dropped by almost half that. The usage was 2% per 0.2 mile trip.



Flat Track testing

¼ Mile Track dark mode

Speed was 10 MPH

1 lap	4%
4 laps	19%
Average of 10 laps	4.5%
Average of 20 laps	5.2%

Flat Track testing

¼ Mile Track One Solar Panel mode
Speed was 10 MPH

1 lap	3%
4 laps	13%%
Average of 10 laps	3.1%
Average of 20 laps	3.0%

Flat Track testing

¼ Mile Track Three Solar Panel mode
Speed was 10 MPH

1 lap	2%
4 laps	7%%
Average of 10 laps	1.8%
Average of 20 laps	1.9%%

Flat Track testing

0.2 Mile Track Parking Lot Dark mode
Speed was 10 MPH

1 lap	4%%
4 laps	14%%
Average of 10 laps	3.7%
Average of 20 laps	3.4%%

Flat Track testing

0.2 Mile Track Parking Lot One solar Panel mode
Speed was 10 MPH

1 lap	3%%
4 laps	12%%
Average of 10 laps	2.7%
Average of 20 laps	2.8%%

Flat Track testing

0.2 Mile Track Parking Lot 3 solar panels mode
Speed was 10 MPh

1 lap	2%%
4 laps	7%%
Average of 10 laps	1.8%
Average of 20 laps	1.9%%

Multilevel track

A multi level track around the center of the campus was used to see the rates of usage with and without the panels exposed. On a percentage basis the cart would go around this 0.5 mile track with about 8% usage without panels exposed and an average of 4.5% usage rate with panels exposed to the sun.

The track gave us several ways we could do accurate testing since the track was a 6% grade up and down hill on two sides and level on the other two sides. The usage up hill was 40 amps average at a slow pace of 10 seconds up hill for 200 feet. The usage could jump as high as 200 amps at fast speeds. The reverse was 5 amps down hills on average. The straight away was 10 – 15 amps on average pending the speed. The track took two minutes to go around at a nice slow pace.

Multi Level track

0.5 miles two level with one side at 6% up grade and one side at a 6% down grade
Speed was 8 MPH
Dark Mode

1 lap	8%
4 laps	30%
Average of 10 laps	8.4%

Average of 20 laps	7.9%

Multi Level track

0.5 miles two level with one side at 6% up grade and one side at a 6% down grade
Speed was 8 MPH
One Panel Mode

1 lap	4%
4 laps	15%
Average of 10 laps	3.7%
Average of 20 laps	3.9%

Multi Level track

0.5 miles two level with one side at 6% up grade and one side at a 6% down grade
Speed was 8 MPH
Three panel Mode

1 lap	2.5%
4 laps	10%
Average of 10 laps	2.3%
Average of 20 laps	2.4%

B. Long Distance track

Fountain Hills is reasonable flat on the road to my house which is 2.5 miles away. The cart was used on a few trial runs back and forth to get an average energy usage. The average 2.5 mile usage rate was 41%. This was at an average speed of 20 miles an hour.

From this the average the range in a fairly non hilly area would be 6.25 miles at optimal speeds of 20 mph.

Long Distance track

10 MPH Average
2.5 Miles away mostly flat
Dark Mode

One way 2.5 miles	41%
Round Trip 5 miles	79%

Long Distance track

10 MPH Average
2.5 Miles away mostly flat
Three Panel Mode

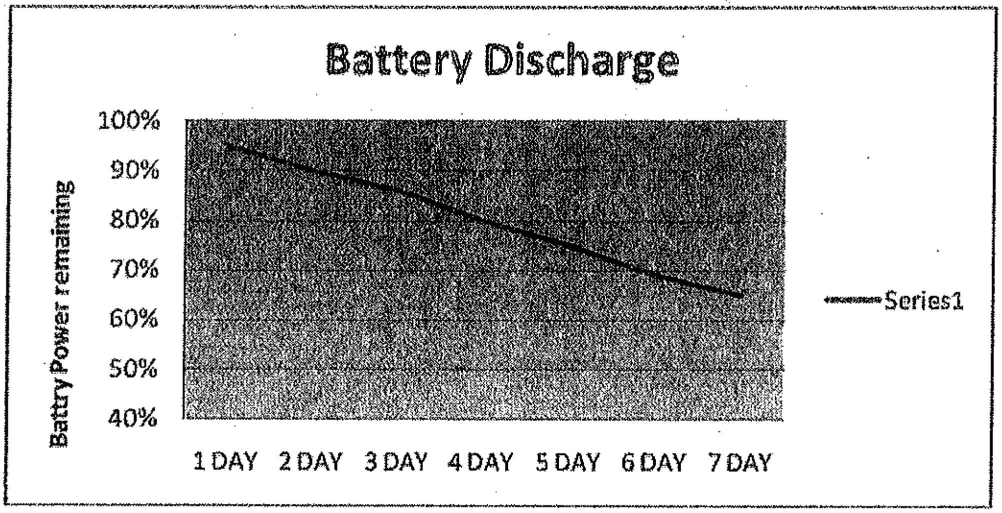
One way 2.5 miles	24%
Round Trip 5 miles	50%

Dark storage:

The cart was dark stored in a garage up to one week at a time. Over the weekend (two days) the cart lost 8% energy. During 5 days storage the cart would lose 20% energy and during a seven day period the cart would lose approximate 30% charge. This averages out to a consistent 4% per day.

Dark Cycle Testing – Discharge Data

Days of dark Storage	Percent Loss in battery energy
1	5%
2	10%
3	14%
4	20%
5	25%
6	31%
7	35%

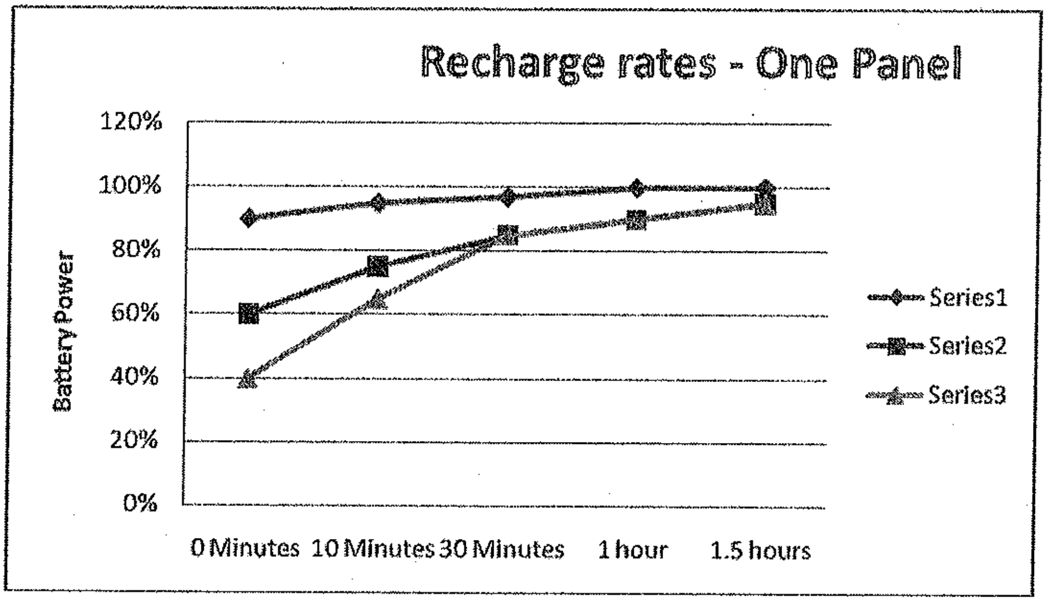


Recharge with and without an active photo panel

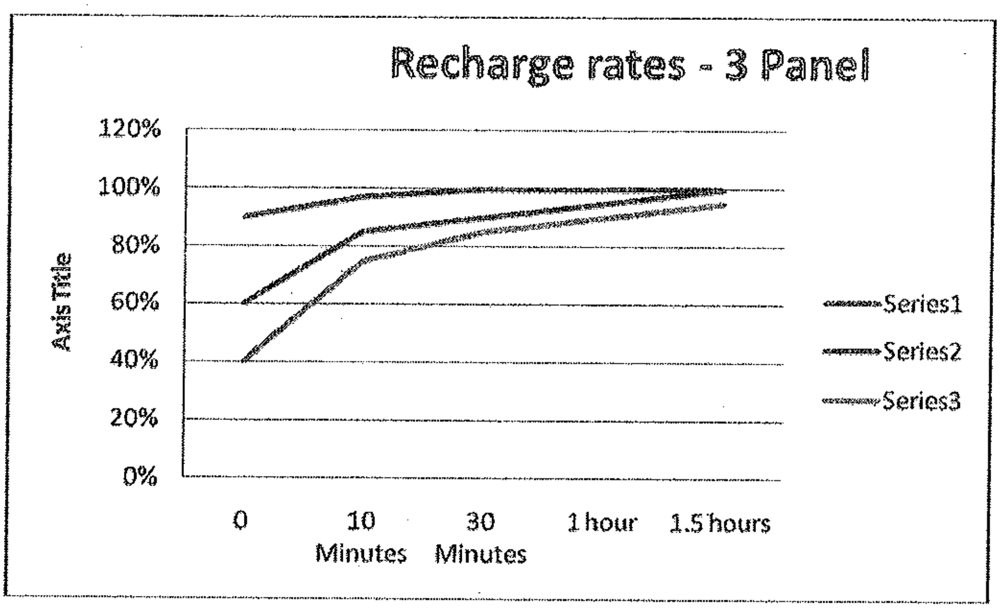
Recharge rates for stopped carts was found to be almost as effective with one panel as it was with three panels. The problem in using one panel is that one panel is not effective in recharging all six 12 volt batteries. The problem of charging two or 4 batteries is the time needed to recharge all the batteries. The possibility of over-charging batteries would be stopped by the regulators but it means two of the batteries would need slow equilibrium recharging. The data taken was for four batteries being recharged by one panel verses all six batteries with all three panels.

We found the active panels would help recharge the carts while in use as much a 40 to 50% more. The panels would however slow down on its recharging (an average of 150 watts / panel max.) when the cart was in active usage.

Studies were done to watch the recharge rates with the cart still and the cart running at 10 mph. The studies demonstrated that the recharge rate at midday was 150 watts per panel but as the cart would start to speed up using as much as 10-20 amps of energy the recharge rate dropped to barely 15 watts per panel. It was a reflection of the usage and current actively being consumed. The more current the less energy the panel was able to deliver to the batteries.



The above rates were for four batteries hooked up.



The above rates were for all six batteries in recharge.

Recharge Rate verses Cart speed
3 panel Mode

0 MPH	150 Watt seconds
1MPH	120 Watt Seconds
5 MPH	35 Watt Seconds

10 MPH	15 Watt Seconds

Recharge Rate verse percentage discharge

1 Panel Mode

Time	Percentage charge
0	90%
10 Minutes	95%
30 Minutes	97%
1 hour	100%

Recharge Rate verse percentage discharge

1 Panel Mode

Time	Percentage charge
0	60%
10 Minutes	75%
30 Minutes	85%
1 hour	90%
1.5 hours	95%

Recharge Rate verse percentage discharge

1 Panel Mode

Time	Percentage charge
0	40%
10 Minutes	65%
30 Minutes	85%
1 hour	90%
2 hours	95%

Recharge Rate verse percentage discharge

3 Panel Mode

Time	Percentage charge
0	90%
10 Minutes	97%
30 Minutes	100%
1 hour	100%

Recharge Rate verse percentage discharge

3 Panel Mode

Time	Percentage charge
0	60%
10 Minutes	85%
30 Minutes	90%
1 hour	95%
1.5 hours	100%

Recharge Rate verse percentage discharge

3 Panel Mode

Time	Percentage charge
0	40%
10 Minutes	75%
30 Minutes	85%
1 hour	90%
2 hours	95%

Recharge rates were somewhat variable with the sun strength. Attempts to recharge were done on days where the sun strength was a consistent 750 watts per square meter.

Efficiency

The cart was used on several up hill trials since it was the most energy consuming point. Going up the hill which places the cart approximately 2 meters higher takes 8 seconds at a 50 amp usage rate which is a 28,800 joules of energy expended by the cart. The cart to take it up 2 meters fully loaded takes 17,600 joules using weight times distance. This is 38% efficiency.

Going down hill it takes only 5 amps on average for the same 10 seconds. This is an 80.01% efficiency.

Effectiveness of keeping the cart off the grid

The cart was tested for a 10 week period and was fully recharged each time by solar energy. The solar panels are sufficient to recharge the cart each day.

Discussion

Discharge and range of a one ton cart.

The cart without photo panels would on average discharge 4% per 0.2 miles or 20% per mile. This means the full range was 4-5 miles on a flat surface. The cart was very consistent in its energy discharge. We routinely ran four full sized people that ran the fully loaded cart to one ton.

When the three photo panels were added the usage rate dropped dramatically. The range grew to over 8 miles. The usage rate dropped to 10% per mile. The recharge rate was slowed by the recharge flow as the cart was exposed to light.

Recharge issues with photo panels.

The optimal recharge method was to either go slow or to stop on occasion. When the recharge rate was checked by amp meter during several runs it was found that the rate dropped to less than a 1/10 of the rate when stationary as the cart approached close to 10 -15 MPH. The best recharge speed was a dead slow 1-2 MPH.

The premise of one single photo panel being enough was quickly becoming obvious that one panel was indeed enough to recharge. When the data one verse three panels were compared the results looked very close. The relative speed of recharge was only slightly faster with multiple panels.

Storage

The storage issues became an issue when the cart was stored over holiday weeks. It was found that the cart lost energy in dark storage daily. It was a consistent 5% loss per day. It showed that long term storage was bad unless the cart electrical was disengaged. It was recommended that the cart should be disengaged after 2 weeks. These results show why.

Recharge rates of different panel situation.

The best way to hook up the batteries became an interesting problem. The batteries are four in the back and two up front. The photo panels were hooked up first to one battery then two, four and all six batteries. The batteries took up to 5 – 10 minutes for the one - four batteries to equilibrate all the six batteries. It was difficult to get consistent data until all six batteries were hooked up. The best arrangement turned out to be three panels, each hooked to two batteries each, This gave maximum energy input and the batteries were matched in voltage to the panels.

Conclusions:

1. A single panel will actually recharge a low charge cart in less than three hours.

2. The single panel gives reasonable recharge rates during usage to extend the cart range from 5 to seven miles with constant usage. Three panels will extend the range to up to 10 miles.

3. Recharge can occur in most golf situations since the cart is idle 50% of the time.

4. The best way to hook the batteries is to get three panels matched in voltage with two batteries. A voltage regulator gives optimal power to the batteries without danger of over charge.

5. Hooking up power to only a few of the batteries that are in series gives false readings of charge. An equilibration time of up to 10 minutes was required.

6. The cart has been off the grid successfully for 10 weeks.

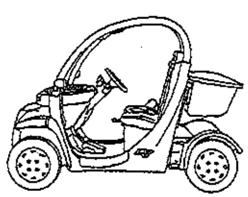
Cart Specification Sheet

GENERAL SPECIFICATIONS

GEM E825 Two Passenger NEV Specifications

Motor: 72-volt shunt GE motor
Transmission: Front wheel drive direct-couple Dana Spicer differential
Speed Control: GE solid state controller with:
* Key Switch Input
* High pedal disable
* Under voltage detector
* Thermal sensor protection
* Zero speed detect "Anti-Runaway"

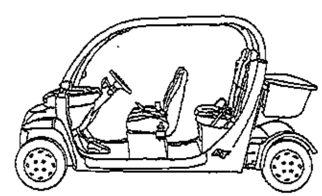
Tire: 10" Two-ply street and turf rated tires
Battery Pack: Six 12-volt deep-cycle batteries
On Board Charger: Proprietary 72-volt DC charger with charge status LED/using 110-volt AC house current
Width: 55 inches
Length: 98.5 inches
Height: 68 inches
Turning Radius: 13' 5"
Wheelbase: 71.1 inches
Curb Weight (empty): 1100 lb.
GVW (loaded): 1600 lb.



GEM E825 Four Passenger NEV Specifications

Motor: 72-volt shunt GE motor
Transmission: Front wheel drive direct-couple Dana Spicer differential
Speed Control: GE solid state controller with:
* Key Switch Input
* High pedal disable
* Under voltage detector
* Thermal sensor protection
* Zero speed detect "Anti-Runaway"

Tire: 12" Two-ply street rated tires
Battery Pack: Six 12-volt deep-cycle batteries
On Board Charger: Proprietary 72-volt DC charger with charge status LED/using 110-volt AC house current
Width: 55 inches
Length: 126.5 inches
Height: 69.75 inches
Turning Radius: 17' 6"
Wheelbase: 101 inches
Curb Weight (empty): 1280 lb.
GVW (loaded): 2100 lb.



2

Voltage Regulator

Voltage Regulator from ETA Engineering

ETA Engineering, Inc.

2010 E. University Dr. Suite 20

Tempe, AZ 85281

Phone: 480-966-1380

Toll Free: 1-877-964-4188

Fax: 1-480-966-1516

info@etaengineering.com

ETA Charge Regulators: Built-in Reliability

Battery Charging Methodology

PBR: Photovoltaic Battery Charge Regulator

9 Amp PBR Charge Regulators

Rated Input Current- 18 Amp

Surge Rating- 36 Amps for 20 sec

Voltage(s) Available- 12, 24, 48 VDC

Mounting Holes- Two 3/16"

Weight- 0.88 lb (0.13 kg)

Dimensions (in)- 4.75 x 3.88 x 1.75

Control Panel Description

INSTRUMENT POD

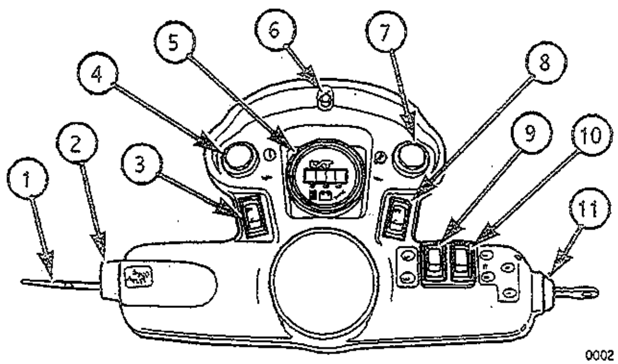


Figure 2 - Instrument Pod

1. Turn Signal Lever
2. Horn Button
3. Light Switch
4. L-Turn Signal/Brake Warning Light
5. Battery Discharge Indicator (BDI)
6. Charge Status Light
7. R-Turn Signal/Seat Belt Warning Light
8. Windshield Wiper Switch
9. Road/Turf Switch
10. Vehicle Direction Switch
11. Key Switch

INDICATORS

Battery Discharge indicator (BDI)

The "Battery Discharge Indicator" (see figure 2), is located in the center of the Instrument Pod and performs the following functions.

1. Battery Discharge Indicator (BDI)
2. MPH Speed Indicator
3. Accumulated Miles
4. Error Code Display

At key on, with the parking brake released, the BDI will display the battery percent of charge. The indicator will then alternate between MPH and battery status. The battery status is displayed in 3 digits and the battery icon will light. For example, 100 equals 100% charge. When the key is turned off, the LED display will show the odometer reading and the hourglass icon will light.

NOTE: If an error code is displayed, it is preceded by a minus sign and the tool icon will light. For a description and explanation of common error codes see the Error Code Summary on page 26.