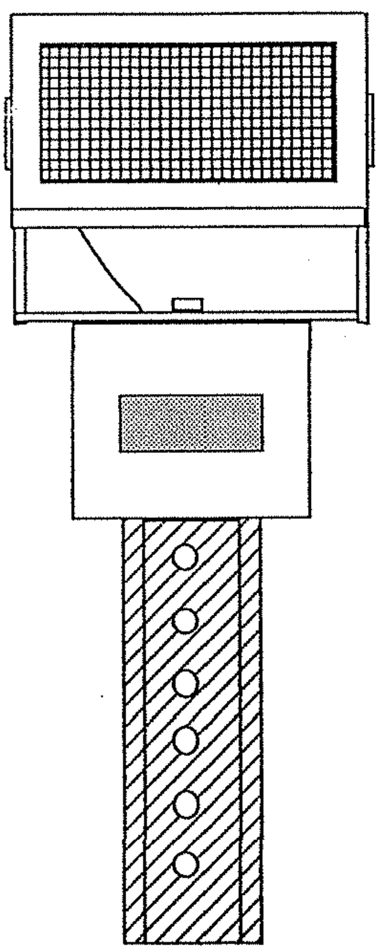
SOLAR POWERED HIGHWAY DELINEATOR SYSTEM



FINAL REPORT FOR HR-367

SOLAR POWERED HIGHWAY DELINEATOR SYSTEM

Final Report for HR-367

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Abstract

Currently, many drivers experience some difficulty in viewing the road ahead of them during times of reduced visibility, such as rain, snow, fog, or the darkness of night. Recent studies done by the National Safety Council provide a detailed contrast between fatal accidents occurring during the day and night. Revealed was that the motor vehicle night death rate (4.41 deaths per 100 million miles driven) was sharply higher than the corresponding death rate during daylight hours (1.21). By providing a delineating system powered by the natural resource of solar power, a constant source of visibility may be maintained throughout the evening.

Along with providing enough light to trace the outline of the road, other major goals defined in producing this delineator system are as follows:

1. A strong and durable design that would protect the internal components and survive extreme weather conditions.
2. A low maintenance system where components need few repairs or replacements.
3. A design which makes all components accessible in the event that maintenance is needed, but also prevents vandalism.
4. A design that provides greater visibility to drivers and will not harm a vehicle or its passengers in the event of a collision.

This solar powered highway delineator consists of an adjustable solar array, a light fixture, and a standard delineator pole. The solar array houses and protects the solar panels, and can be easily adjusted to obtain a maximum amount of sunlight. The light fixture primarily houses the battery, the circuit and the light assembly. Both components allow for easy accessibility and reduce vandalism using internal connections for bolts and wires. The delineator mounting pole is designed to extensively deform in the event of a collision, therefore reducing any harm caused to the vehicle and/or the passengers. The cost of a single prototype to be produced is approximately $70.00 excluding labor costs. However, these material and labor costs will be greatly reduced if a large number of delineators are produced.

It is recommended that the Iowa Department of Transportation take full advantage of the research and development put into this delineator design. The principles used in creating this delineator can be used to provide an outline for drivers to follow, or on a larger scale, provide actual roadway lighting in areas where it was never before possible or economically feasible. In either event, the number of fatal accidents will be decreased due to the improved driver visibility in the evening.

Table of Contents

Recommendations

Prior to any further research and development of this design, the project group would like to make several recommendations concerning the future of the product.

The first recommendation to be made is regarding the construction of the unit. It is recommended that the unit be constructed of an extremely durable plastic material that would be both lightweight and corrosion resistant. In the event that a plastic can not be found, it is recommended that a 316 stainless steel be used for its strength and extreme corrosion resistance.

Next, the group would like to suggest some possible uses for the delineator. In the event that this unit is to be tested or actually used, the group suggests that the delineator be used to indicate changes in road patterns, construction zones, exit ramps, or other potentially dangerous areas on the road. If the unit is tested, it is recommended that a thorough test procedure be devised in order to answer such questions as:

Does the design improve the drivers visibility?

Does the charge system and circuit function properly over an extended period of time?

Is the design reasonable?

Can we benefit from this design?

These questions can only be answered after a thorough analysis of the design has been completed.

Due to the limited time spent on the project, there are several recommendations the group would like to make in an effort to provide a quality delineator unit. These suggestions are as follows:

-Attempt to contain all wires internally if possible to further reduce vandalism.

-Apply a highly reflective paint or reflectorized banding to the unit to provide even greater visibility and to serve as a backup in the event of an internal failure.

-Weather sealing and light fixture insulation may be needed to prevent damage to the circuit under extreme weather conditions.

When considering this design, it is important to keep in mind the annual cost of energy, maintenance, and responsibility for the maintenance. It is also important to consider the costs involved in poles, brackets, and other weather exposed components that may need to be replaced.

Finally, it is recommended that the Department of Transportation take full advantage of the groups research and design. It is quite possible that some ideas for providing various lighting systems may develop from this simple design in the future.

Conclusions

In reviewing the accomplishments made by the design group, it would be important to review the goals set at the beginning of the semester. First, the group wanted to provide a low maintenance design with accessible components. This was accomplished by researching internal components and investigating their lives. The minimum expected life of any component is approximately two years. Occasionally the design needs to be adjusted to maximize the amount of sun collected, but this needs to be done twice a year if the tilting procedure is followed. This design also provides easy access to all replaceable components for easy maintenance.

The group also wanted to provide a strong and durable design that was still safe for use on highways. The prototype was constructed of 303 stainless steel, which was primarily chosen for its strength and extreme corrosion resistance. Once this unit is mounted to a standard delineator post, the design will be considered safe for highway use. This pole will reduce damage to the vehicle and its passengers by extensively deforming in the event of a collision.

While still being an accessible design for maintenance purposes, the group wanted to ensure that vandals were not able to remove or damage the unit. Using internal connections of most bolts and wires, the group feels that the design will reduce the possibility of vandals damaging or stealing the unit. Any bolt connections that are made externally will require use of an Allen wrench to adjust the hex-head cap screws.

The final goal of the group was to provide a working model or prototype of this design. Unfortunately, much of the work done by the group consisted of research and computations. When the analysis was complete, we were left with limited time to produce a working prototype. However, the group complete the prototype array design and produced a model circuit. Had there been another week or two to complete the project, the group feels that the design would have been completed. This time would have included manufacturing and final testing periods.

Regardless of the one goal left unaccomplished, the group feels that a quality delineating system has been developed under a limited amount of time. A large amount of time and effort was put into this design, and hopefully it will not go to waste. Each one of us has gained quite a bit of experience and education that will remain with us for the rest of our lives. The group hopes that this design will be seriously considered and further researched by the Department of Transportation. Hopefully the solar powered delineating system and/or its principles can be used to provide better night visibility for drivers, ultimately saving valuable lives.

Introduction

Currently, many drivers experience some difficulty in viewing the road ahead of them during times of reduced visibility, such as rain, snow, fog, or the darkness of night. While precipitation is generally unpredictable, darkness is a daily occurrence where visibility is highly dependent upon a vehicle's headlights and any available street lighting. This project aims at controlling the visibility factor due to darkness in certain hazardous areas.

Recent studies by the National Safety Council[1] provide a detailed contrast between fatal traffic accidents occurring during the day and night. Out of an estimated 43.5 thousand total deaths due to traffic accidents, more than one half occurred at night, while approximately one third of the total occurred in rural areas at night. In a second study, the Safety Council also distinguished death rates by day and night, where the death rate was defined as the number of deaths per 100 million vehicle miles driven. Revealed was that the motor-vehicle night death rate (4.41) was sharply higher than the corresponding rate during daylight hours (1.21). This essentially means that a driver is approximately 3.5 times more likely to be in a fatal traffic accident at night.

Many highway departments have taken a strong step in attempting to reduce night time fatalities. By placement of small reflectors either separating highway lanes or along the

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[1] National Safety Council, Accident Facts 1992 Edition, facts based on reports from 16 state traffic authorities.

side of the road, an additional source of visibility is provided. The problem with the current reflectors is that they are a variable light source primarily dependent upon a vehicle's headlights. The aim of this design is to provide greater visibility for night driving and reduce the evening death rate. This design converts solar energy into electrical energy during the day, storing this energy into the evening. At sundown this energy, stored in a rechargeable battery, powers a light bulb to provide a constant delineating device through the evening.

Goals

The project group has defined major goals in producing the solar powered highway delineator system. One of which was to provide a working prototype by the completion of the semester. Day by day this goal is becoming more of a reality as calculations and analysis are performed. Other goals included providing adequate accessibility, strength and durability, safety, and low cost.

Due to the fact that the delineator system would generally not be under constant supervision, it is essential to provide a system as maintenance-free as possible. However, under routine maintenance an occasional bulb or battery may need to be replaced. Considering this, the system would need to provide accessibility for maintenance while utilizing some kind of locking mechanism in an attempt to deter thieves or vandals from stealing or destroying the system's components. Providing a maintenance-free product would also add to the cost-effectiveness of the system by controlling future costs.

Of major importance in the design of the delineator system is safety. Indeed the system would provide increased night driving safety, but consideration must be given to what may happen should a vehicle veer off of the road and strike part of the system. These attempts to produce a safe design are further discussed in the following sections.

Design Process-Analysis

Before any type of design project begins, background information must be researched and preliminary analysis on the design's capabilities and expectations must be done. An important amount of information came from standards involving the delineator design. Although there are no standards that directly apply to a solar powered delineator, there are several safety factors that are used in roadway lighting systems that were also applied to the design of this delineator system. These standards, as quoted from *An Informational Guide to Roadway Lighting* (prepared by the American Association of State Highway and Transportation Officials), are as follows:

1. It is desirable to place poles outside the roadside clear areas whenever practical. The roadside clear area is defined as an area adjacent to the roadway, free of obstacles or hazards, which provides the driver of an errant vehicle a reasonable opportunity to recover control of her/his vehicle.
2. Pole locations should consider the hazards in servicing the lighting equipment.
3. Poles should never be placed on the traffic side of a guardrail or any natural or man-made barrier.
4. Where poles are located in exposed areas, they shall be designed to have a suitable breakaway or yielding feature. This safety feature may take any one of several forms which have been used by highway agencies with

satisfactory results. One such feature is a breakaway or yielding base which shall be designed to yield when struck by a vehicle, thereby minimizing injury to the occupants of the vehicle and damage to the vehicle itself. This safety feature shall comply with all applicable AASHTO requirements for structural supports. (It is interpreted that by yielding, the support structure will deform extensively upon impact.)

5. Poles that are exposed to freeway traffic should, where possible, be located at least 15 feet (4.6 meters) or more from the edge of the traveled way.

It was also necessary to do an extreme amount of research into the area solar power. It was determined that a 2.33 volt bulb with a current draw of 100 milliamperes would be used in the design. Given this information, it was determined that the battery powering this bulb would need to be a 2 volt battery with a 2.5 ampere hour storage capacity. In choosing the solar array, the current output needed tc be quite high in order to charge the battery in time. It was also known that the voltage output from the array needed to be at least 2 volts to equal the battery and the bulb. The cells selected from the Edmund Scientific Catalog provided an output of 800 mA and .45 volts. It was then determined that 5 cells wired in series would provide approximately 800 mA and 2.5 volts during peak sun hours. The calculations and criteria for choosing these components are tabulated in

Appendix 1. Using the battery specification chart provided by Gates Energy Products, it was determined that the battery would fully discharge after approximately 30 hours of use. This would provide for approximately three days of no sunlight as well as other factors that would limit the amount of sun received by the unit, such as location and accessibility. In looking at the reverse situation, the battery could be fully charged with the maximum output from the array in approximately 3 hours. All battery specifications can be found in Appendix 2.

Design Process-Synthesis

After considering many ideas, the group decided on an individual solar powered delineator that would be mounted on the side of the road. This design, when placed within a group of such individual units, would be used to alert drivers of exits, curves and construction zones. This delineator was designed as a portable device enabling the product to be used at temporary road construction sights as well as permanent installations.

The two areas of major concern in the synthesis of the delineator were the solar array and the light fixture that would do the actual delineating. In taking advantage of solar energy, it is necessary to collect sunlight using solar cells. Although the group did not develop an individual solar cell, the group did design and construct the photovoltaic array. A photovoltaic array is a collection of solar cells assembled to convert solar energy directly into electricity.

The first step of the array design process involved the numerical analysis discussed above. The array size and power requirements were determined in order to continue with the array design. The synthesis of the array took into consideration this analysis so that the size and power requirements of the array could be matched with solar cell manufacturer specifications. Once these specifications were matched, the group purchased the solar cells from Edmund Scientific Co. and tested them to ensure reliability in their future application. This will significantly reduce possible problems in repairs and will decrease the risk of severely damaging the array. The only equipment required to test a solar cell is a multimeter, a standard solar cell of known output, and a proper light source. A proper light source could be sunlight, a solar simulator, or even a slide projector lamp.

Once the cells were connected and the array was completed, an external frame was constructed for further protection of the solar cells. Several factors were addressed in designing the frame. The size of the frame had to be large enough to contain the array (8" x 6.5"). It also had to be small enough to be used as a portable unit. The materials used in constructing the frame needed to take into account expansion and contraction of the solar cells during temperature changes, as well as being durable enough to provide protection from vandals and extreme weather conditions. A frame (8.5" x 7.75" x 1") made of 20 gauge 303 stainless steel was developed to hold and protect the array. The 303 stainless steel was primarily chosen for its strength, durability, and corrosion resistance. To allow for wiring of the unit, a hole was placed in the back side of the frame. The cells were essentially sandwiched between four pieces of Plexiglas within the frame to allow for the expansion and contraction of the array. The array sits directly upon a Plexiglas backing plate which has five 1" x 2.75" slots to allow for the array terminals. Two Plexiglas strips are glued to the backing plate to prevent the array from sliding around. Finally, a Plexiglas cover is placed over the array to provide protection for the array while allowing light to reach the solar cells. This assembly can be seen in Figure 1 below. The final plans for the array are shown in Appendix 3.

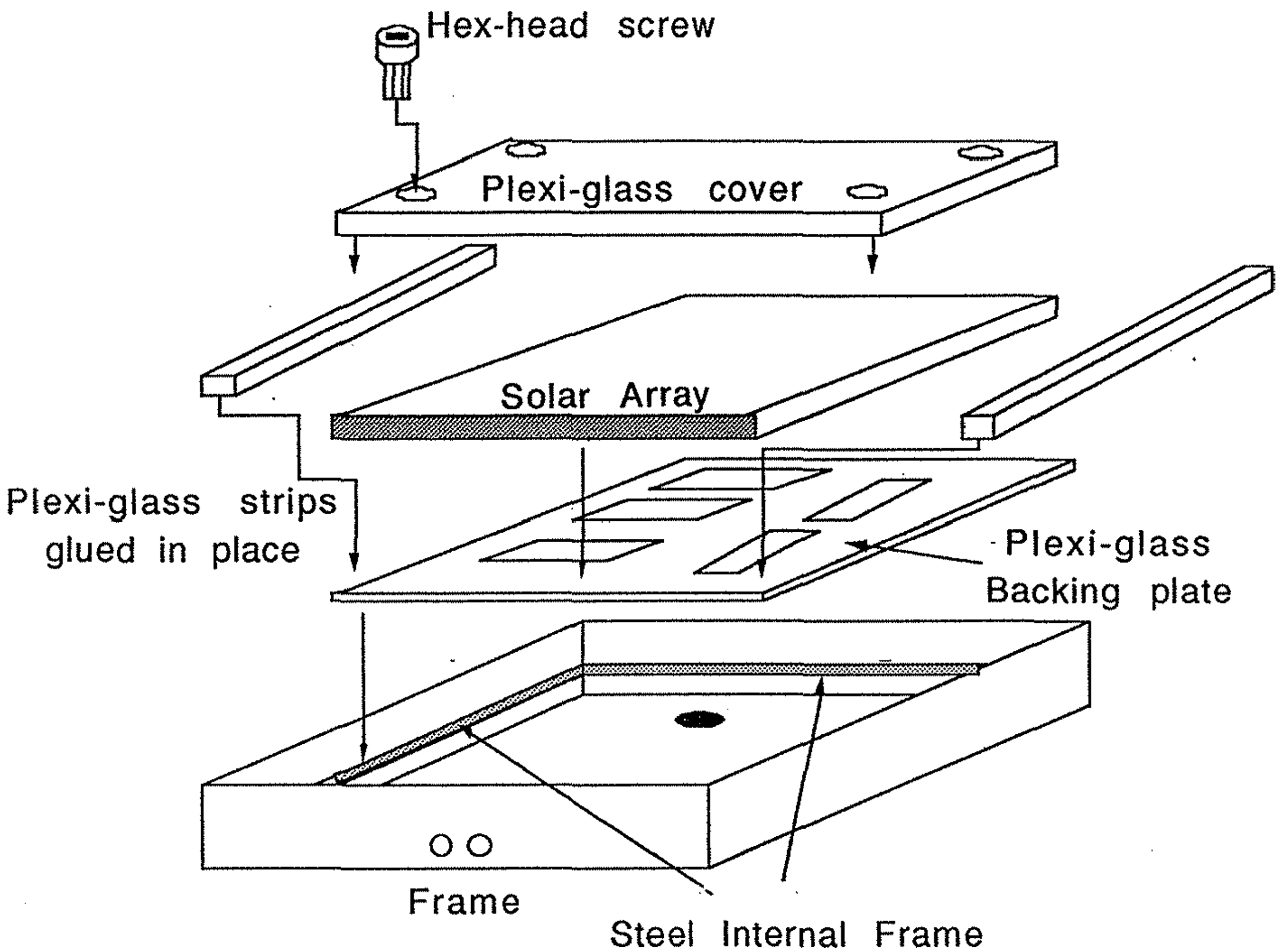


Figure 1: Array Assembly

There was also a consideration of mounting the array to the delineating device. This included array-to-battery wiring and the capability of the array to adjust to the position of the sun at different times of the year. Rotating and tilting the array to various positions will help maximize efficiency and voltage output from the array through approximated tracking of the sun. Since the delineator will be placed at different locations, the array will need to be rotated in order to face the sun directly. The array should also be tilted from the horizontal position an amount equal to the degrees latitude of the units location. To further increase efficiency, the tilt angle should be increased 15 degrees (from its original position) during winter months, and the tilt angle should be reduced 15 degrees (from its original position) during summer months.

In designing the delineator, an electrical circuit was developed to take advantage of the electricity being supplied by the photovoltaic array. Although a very simple circuit (Figure 1), care must be taken to ensure that there are no unnecessary malfunctions that may cause permanent damage to the delineator.

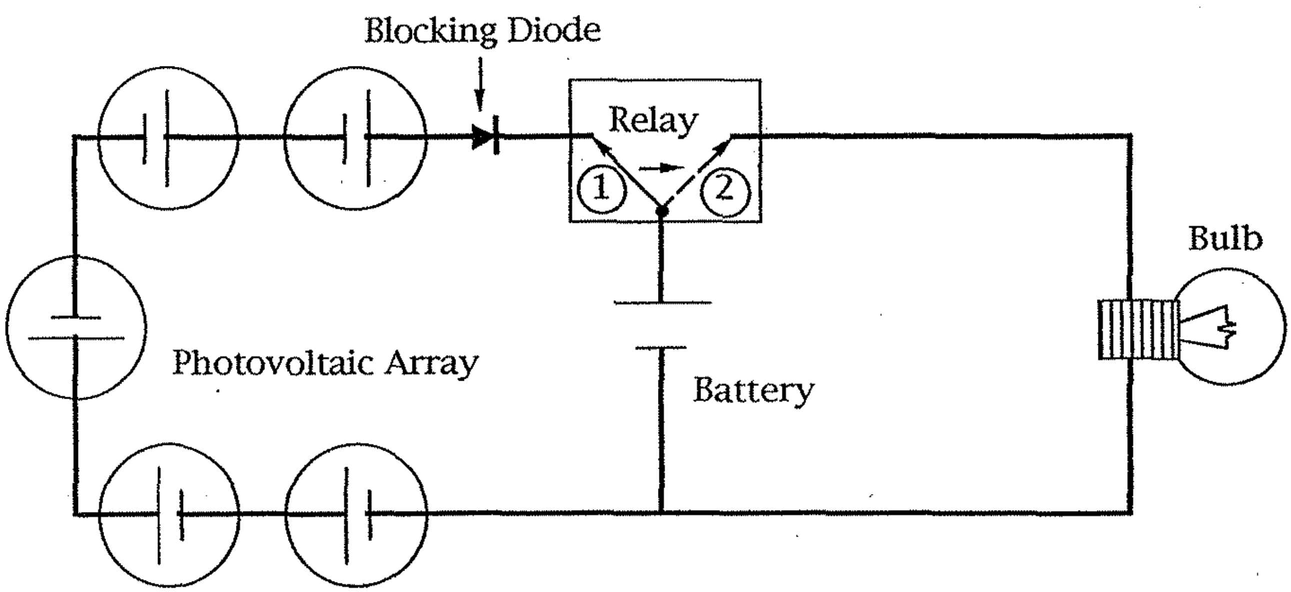


FIGURE 2: Simple Circuit

The batteries will be charged by the photovoltaic array during the day, providing enough energy to power the bulb (load). The blocking diode in the illustration prevents the current in the charged battery from seeping back into the array when power is no longer being generated. The current is only allowed to flow toward the load. This not only helps keep the lamp operational, but also extends the life of the storage batteries. The relay in the figure is what actually switches the system from "charge" to "light" mode. In situation 1, power from the array is sensed by the relay and allows the battery to be charged. When the sun goes down, power is no longer produced. The switch closes to position 2 which allows the battery to power the bulb. This cycle then repeats when the sun rises. The storage batteries that will be used are lead-acid rechargeable batteries which are typically used in small solar powered systems like the delineator. The advantages to using the lead-acid batteries are their long life capabilities and reduced maintenance requirements. Safety concerns regarding rechargeable batteries and their containing systems may be found in Appendix 4.

While the circuit was being designed, plans for the actual light fixture were also being developed. In considering the component which would actually delineate the road, several factors were addressed. First, the battery, circuit, and light assembly must all be protected from the weather, vandals, and other items that may cause damage. While providing all of this protection, the replaceable components had to be accessible. And finally, the battery and circuit needed to be contained to prevent any potential hazards.

The actual light fixture is made up of six separate parts which are easily assembled, as shown in Figure 3 below.

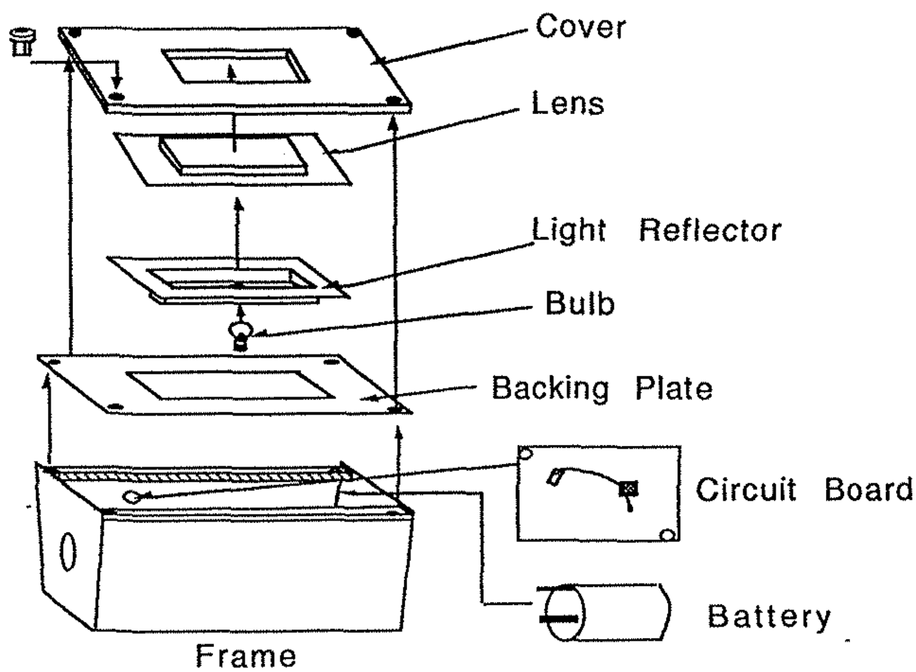


Figure 3: Light Fixture Assembly

The frame is primarily for support and housing of the internal components, as well as providing an aesthetic appearance. A light assembly consisting of a reflective backing, bulb support, and lens cover are sandwiched between the fixture cover and a backing plate. The backing plate primarily holds the light assembly in place. This arrangement is then fastened to the top of the frame, enclosing all components.

Once both components are completed, they are mounted to a standard delineator pole already used by the Iowa

Department of Transportation. This pole is considered a breakaway support structure which will deform extensively when struck by an oncoming car. This ultimately prevents serious damage to both the vehicle and its passengers. It is important to note that this pole design meets all applicable standards defined by the American Association of State Highway and Transportation Officials.

As mentioned earlier, many of the connections are made internally. This means that when possible, any components that need to be fastened are done so inside of the light fixture. This is done primarily as an effort to reduce the possibility of vandalism. This internal fastening is done when the array is mounted to the light fixture and when the unit is mounted to the delineator pole. Any other fastening done externally will utilize hex-head cap screws. This will be used for attaching the cover to the light fixture, and to fasten the array to its mount. Although vandals could purchase wrenches to remove the hex-head cap screws, they are much less common than simple adjustable wrenches.

Evaluating the design goals of this unit with what has been accomplished throughout the semester, the following items can be easily observed:

1. A strong and durable design that protects all internal components has been provided.
2. The design is fairly low maintenance, where all replaceable components have long life properties.

3. The design makes all components accessible in the event that maintenance is needed, but also prevents vandalism.
4. The design provides a constant source of visibility to drivers and will not harm a vehicle or its passengers in the event of a collision.

The group's final schedule concerning the design of the single delineator unit can be followed using the Gantt chart displayed in Appendix 6. As the chart will show, the project group has accomplished nearly all of the initial goals, with the only exceptions being the completion of a working prototype and the final testing of that prototype.

One of the major goals in producing the solar powered delineator unit was low-cost. The cost of a single prototype to be produced is approximately $70.00 excluding labor costs. However, these material and labor costs will be greatly reduced if a large number of delineators are produced. A detailed cost breakdown is tabulated in Appendix 5.

The project group believes that this delineator can be extremely beneficial to the Department of Transportation. With further research and development, solar power could be used by the DOT on various levels. For example, on a larger scale, actual roadway lighting systems could be designed to take advantage of solar power following the same principles as this delineator. With a low operating cost, it would be possible to provide roadway lighting in areas where it was never before possible or economically feasible. Thus fatal accidents would decrease with the improved vision created for night drivers.

Appendix 1

Calculations

Calculations

Light Bulb Specifications:

2.3 Volts
0.1 Ampere
2 Years Approximate Life

Solar Cell Specifications:

0.45 Volts/cell
0.8 Ampere/cell

Choose Battery
(Refer to Discharge Characteristics: Figure 4: Appendix 3.)

The battery was chosen by extending a line vertically from the Duration of Discharge axis on the Discharge Characteristics Chart. With a discharge current set at 0.1 ampere from the light bulb, this shows that the Gates 2.5Ah D cell would supply adequate power for a period of 10 hours. Extending the D cell linear curve to the 0.1 Discharge Current gives a maximum fully-charged discharge time of 30 hours. This would essentially result in a total of 3 " no sun " days assuming that the bulb will run approximately 10 hours per 24 hour period.

Determination of Number of Solar Cells Necessary

Voltage Required by Battery:	2.0 volts
Voltage Provided by Single Solar Cell:	0.45 volts

Dividing the voltage required by the battery to charge by the voltage provided by a single solar cell gives a value of 4.44. This indicates that a total of 5 solar cells wired in series would provide enough voltage to effectively charge the battery.

Appendix 2

Battery Specifications

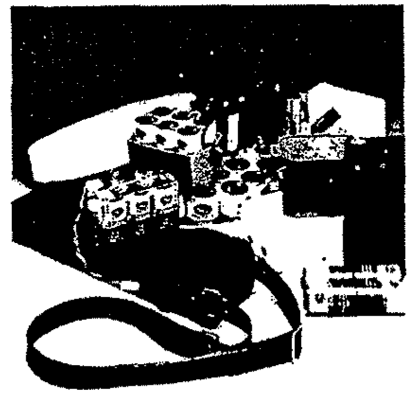
Cyclon Cell/Battery Performance Benefits

Gates Energy Products Battery Selection Guide for Cyclon Cells and Batteries contains specifications for the four basic cell sizes, standard Cyclon batteries and Cyclon monobloc batteries.

Gates sealed rechargeable lead acid cells and batteries solve many of the problems associated with "conventional" types of batteries. The sealed construction utilizes a patented starved electrolyte system providing numerous advantages discussed below.

In addition to the wide range of standard configurations, Gates Cyclon cells offer a high degree of flexibility to meet unusual requirements. They can be custom assembled in an almost infinite variety of configurations to precise voltage and amp-hour needs.

For more information on any Gates Standard batteries or if you have any special requirements, please contact your Gates Energy Products sales office or distributor.



Special Batteries

Long life	In float, typically 8-10 years at 23° C before the battery will fall to 80% of rated capacity. In cyclic applications, 200 to 2,000 cycles, dependent on depth of discharge.
Superior high rate performance	Due to low internal impedance, the Gates cell gives high discharge currents and fast recharging times. This may make it possible to use a smaller battery package than an equivalent conventional battery.
Excellent low temperature performance	At −40° C, Cyclon cells will deliver 50% of C/10 room temperature capacity, where conventional lead acid batteries deliver 25% to 30% capacity at this temperature.
Long storage life	Cyclon cells can be stored for up to 3 years from a fully charged state at room temperature without recharging or damage to the cell.
No acid spills or vapor damage	Gates cells don't dry out and do not vent acid or acid vapor, so they can be used near delicate electronic circuitry. The self-resealing safety vent allows for abusive overcharge or charger failure without cell rupture.
Ease of charging in float applications	A constant voltage float charge of 2.35 volts per cell (no current limit required) will provide an 8-10 year expected lifetime. Chargers of this type provide a 90% recharge in as little as 5 hours, depending on current output.
Efficient fast charging in cyclic applications	The Gates battery can be fully recharged in less than one hour, using a constant voltage charger with current in the 5C range. Cyclon cells and batteries can be charged or discharged in any position and will not lose electrolyte during normal charging.
High reliability and durability	Cyclon cells and batteries offer excellent mechanical and vibrational strength.
Dry cell classification	All Gates Energy cells and batteries are classified as "dry" by the US Department of Transportation and by the International Air Transport Association and are not subject to Restricted Articles Regulations covering air shipment.

Cyclon Single Cell/Batteries Performance Specifications

Gates Energy's Cyclon cells are available in four basic sizes and may be combined to form batteries of varying sizes and capacities.

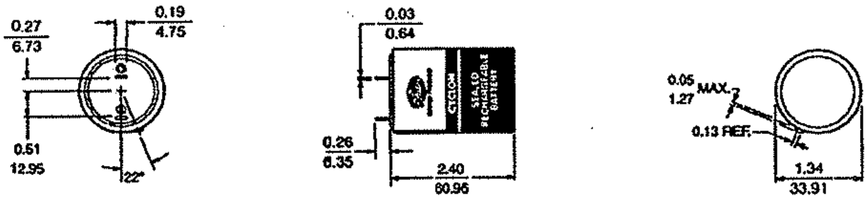
Each cell is encased in a metal can, electrically isolated to prevent accidental shorting, and incorporates a self-resealing safety valve which will vent under abusive overcharge conditions at an internal pressure of about 50psi.

Typical Specifications (Ta=25°C)	**D Cell – 2.5Ah**	**X Cell – 5.0Ah**	**J Cell – 12.5Ah**	**BC Cell – 25.0Ah**
Product Number	0810-0004	0800-0004	0840-0004	0820-0004
Capacity Rating				
20 hour rate	2.7Ah	5.4Ah	13.0Ah	26.0Ah
10 hour rate	2.5Ah	5.0Ah	12.5Ah	25.0Ah
1 hour rate	1.8Ah	3.2Ah	9.0Ah	17.5Ah
Cell Power Rating				
Peak Power	(@135A)135W	(@200A)200W	(@350A)325W	(@600A)600W
Energy/Unit Volume (@ C/10 rate)	1.47 W-h/in³ 0.09 W-h/cm³	1.48 W-h/in³ 0.09 W-h/cm³	1.48 W-h/in³ 0.09 W-h/cm³	1.47 W-h/in³ 0.09 W-h/cm³
Energy/Unit Weight (@ C/10 rate)	12.5 W-h/lb 27.5 W-h/kg	12.3 W-h/lb 27.17 W-h/kg	13.5 W-h/lb 29.7 W-h/kg	14 W-h/lb 31 W-h/kg
Internal Resistance (max. for a charged cell)	10×10^{-3} ohms Measured on Hewlett-Packard 4328A milliohm meter.	6×10^{-3} ohms	4×10^{-3} ohms	$.3 \times 10^{-3}$ ohms
Nominal Cell Voltage	2.0V	2.0V	2.0V	2.0V
Cell Temperature Range	Storage Discharge Charge	−65°C to +65°C −65°C to +65°C −40°C to +65°C		
Recommended Maximum Storage Time before Recharge	Ta=23°C	12 months		
Atmospheric Pressure Range	0-8 Atmospheres			
Cell Charging	Constant Voltage cyclic float Constant Current cyclic, maximum float, maximum	 2.40-2.60V 2.30-2.40V C/3 rate for D, X, J cells, C/5 rate for BC cells C/500 rate		
Cycle Life	200-2,000 cycles	200 cycles — 100% depth of discharge, one cycle per day (Charge: 2.45V constant voltage, no current limit; Discharge: C/5 rate); 2000 cycles — 25% depth of discharge (Charge: 2.45V/cell for 7.5 hrs. — 2.0A current limit; Discharge: C/2 rate for 30 min); More cycles are available with shallower discharges. BC cell is for float applications only.		
Expected Float Life	8 years	Based on accelerated test methods, 2.35 volts constant voltage charge at 23°C ambient temperature.		

Mechanical Specifications

All Dimensions = Inches / Millimeters

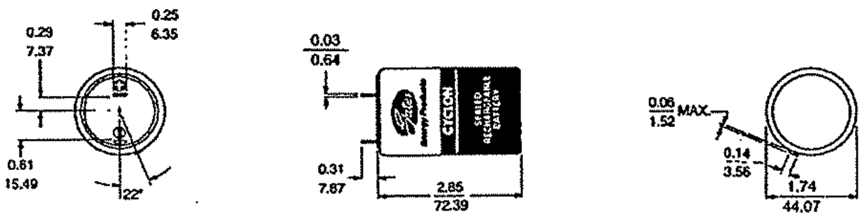
D Cell



Length	2.65 in./67.31 mm
Width (dia.)	1.34 in./33.91 mm
Weight	6.4 oz./182 gm
Tabs	0.19 in. × 0.03 in. 4.75mm × 0.64mm

U.S. Patent Numbers 3,704,173-3,862,861

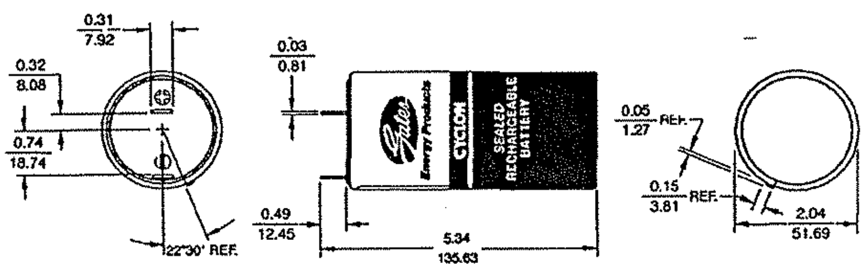
X Cell



Length	3.16 in./80.26 mm
Width (dia.)	1.74 in./44.07 mm
Weight	13.0 oz./369 gm
Tabs	0.25 in. × 0.03 in. 6.35mm × 0.64 mm

U.S. Patent Numbers 3,704,173-3,862,861

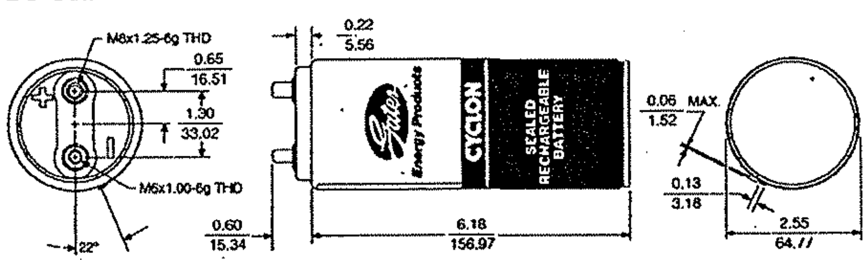
J Cell



Length	5.34 in./135.63 mm
Width (dia.)	2.04 in./51.69 mm
Weight	1.85 lb./.84 kg
Tabs	0.31 in. × 0.03 in. 7.92 mm × 0.81 mm

U.S. Patent Numbers 3,862,861-3,839,093

BC Cell



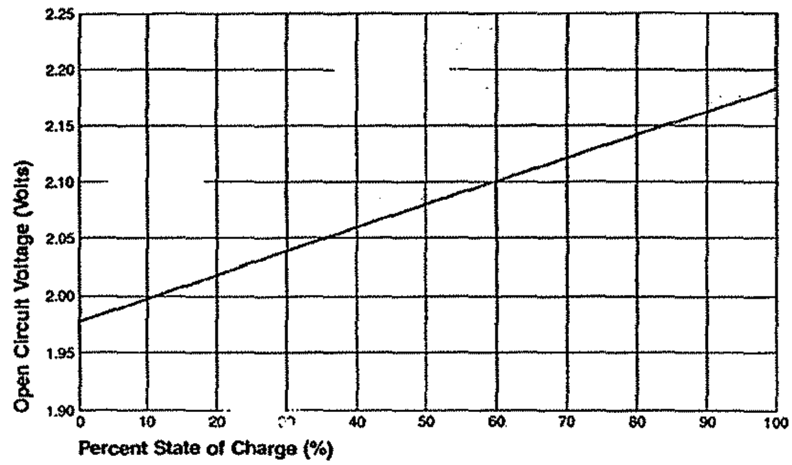
Length	6.78 in./172.31 mm
Width (dia.)	2.55 in./64.77 mm
Weight	3.49 lbs./1.58 kg
Studs	M6 × 1-6g THD M8 × 1.25-6G THD

Terminal torque must not exceed 35 in. lbs. (3.95 nm)

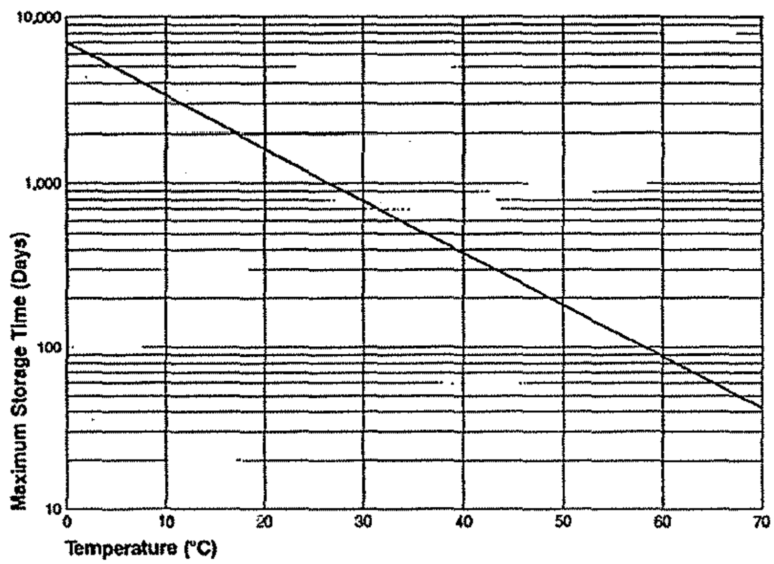
U.S. Patent Numbers 3,862,861-3,839,093

Performance Characteristics

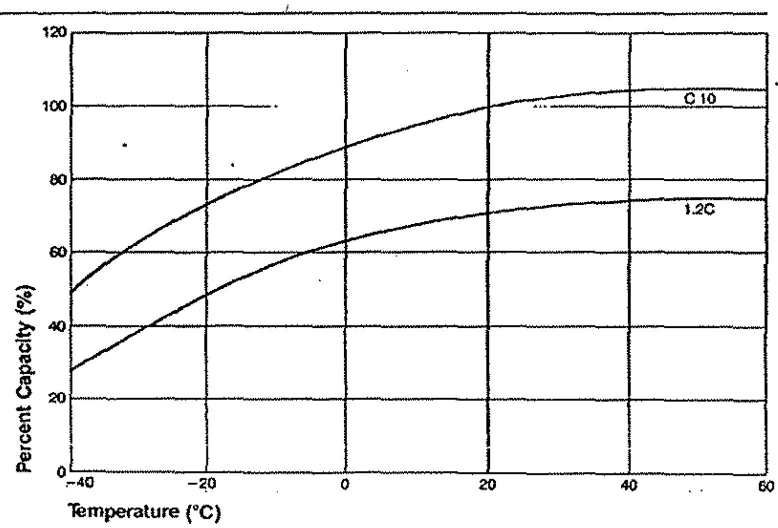
State of Charge
This curve of OCV vs state of charge is accurate within 20% of the rated capacity of the cell being measured if it has not been charged or discharged within the past 24 hours. The accuracy increases to 5% if the cell has not been charged or discharged within the past 5 days.



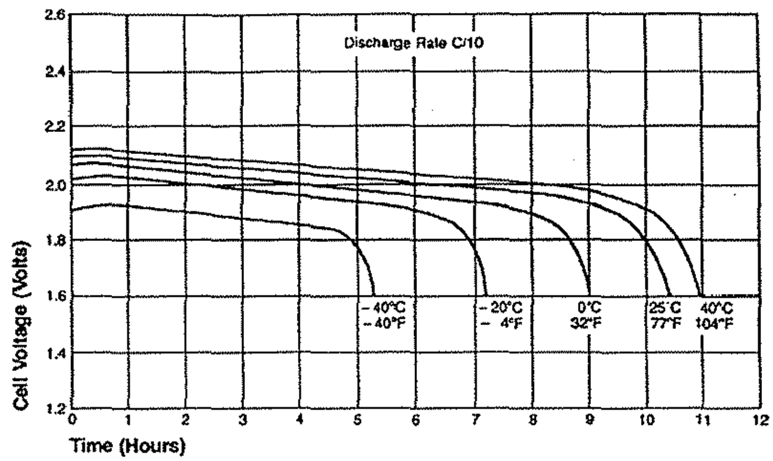
Storage Characteristics
Storage time is very dependent on the storage temperature as shown in this maximum allowable storage time versus temperature curve for a fully charged cell.



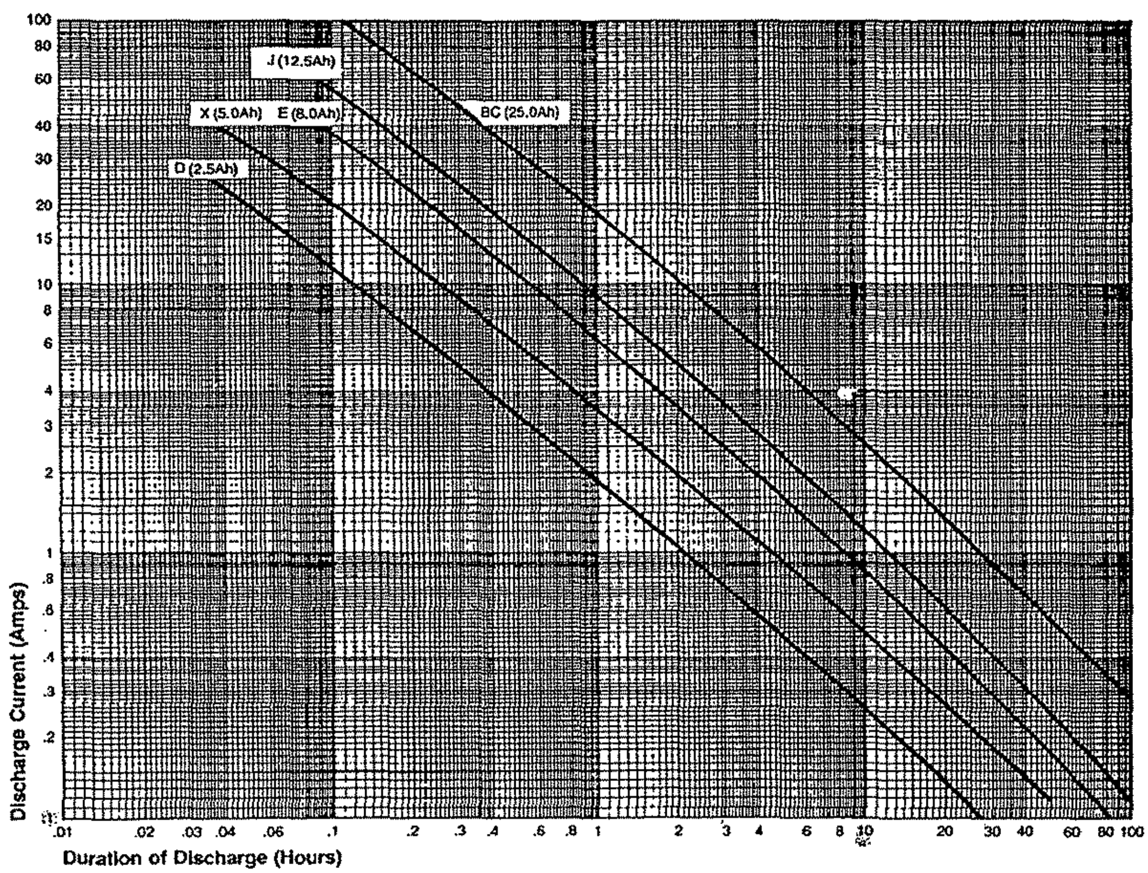
Temperature Characteristics
This graph illustrates the capacity available in the cell as a function of temperature at two different discharge rates.



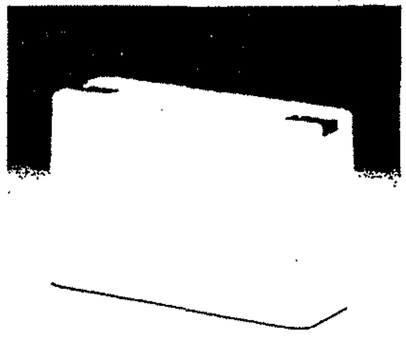
Voltage Regulation
The voltage regulation of the Gates cell is equal to or better than any other commercially available system. Typical curves shown.



Discharge Characteristics
New cells must be cycled appropriately before full rated capacity, as shown on this curve, is reached.



Standard Battery Descriptions



Case

Shrink

Standard batteries offered are based on combinations of the previously described Cyclon cells and are available in 6, 8 and 12 volt configurations with capacities ranging from 2.5Ah to 25Ah.

Battery Packages
Either rigid plastic cases or shrink wrap containers are available.

Rigid Plastic
Cases are either flame-retardant ABS Cycolac (Borg Warner) material, meeting UL94V-0 flammability rating, or *Styrene (available only in 2x3 D and X* battery configurations). Some cases have mounting holes. Rigid plastic cases are recommended for applications in which the battery must withstand vibration, movement or effects of weather.

Shrink Wrap
Packaging is less expensive and smaller in size and weight. A plastic extrusion insulates the battery top and keeps the cells in line and a heavy duty shrink sleeve holds the cells firmly in place. Shrink wrap packaging is recommended for applications in which the battery remains stationary.

Battery Terminations

Tab Stud

D cells—.187" X .025"
X cells—.250" X .025"
J cells—.312" X .032"
BC cells—6mm Post (Neg.),
8mm Post (Pos.).

All terminals are tin-plated steel.

Tab Adapters
Available to convert .187" tabs to .250" *tabs and vice versa.*

BC Quick Disconnect Terminals
AMP series 250 Faston terminals are available for BC batteries.

Connection Terminations
A wide variety of terminations are available. Please specify or contact your GEP Sales Engineer for recommendations.

Fusible Links
Specify your requirement.

Lead Wires
Stranded copper wire with insulation meeting UL1015 specifications (Red+, Black−). Standard leads extend 9 inches outside the battery pack. Ends are stripped and dipped in wax which must be removed before use.

Standard wire gauges are:

D batteries	18 AWG, UL1015
X batteries	16 AWG, UL1015
J batteries	14 AWG, UL1015
BC batteries	12 AWG, UL1015

Varying lead lengths and gauges are also available; please specify to your battery assembler.

The battery dimensions in this catalog are for reference only. For toleranced dimensions contact GEP.

Intercell Connections

Standard

D, X and J batteries – welded tin-plate steel connector.

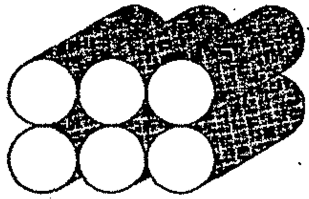
BC batteries – solid copper.

For Vibration-Prone Applications

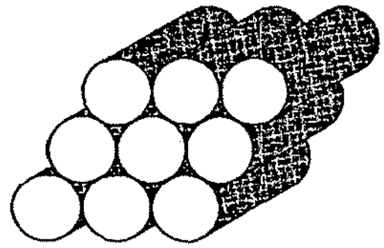
D and X batteries – soldered, stranded wire.

BC batteries – braided copper straps.

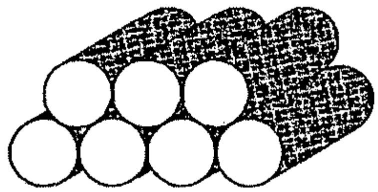
Alternative Battery Configurations
Standard battery configurations are rectangular arrangements. Other possible configurations are illustrated and can be held together with tape (offering the lowest cost and minimum electrical and mechanical protection) or by shrink wrapping.



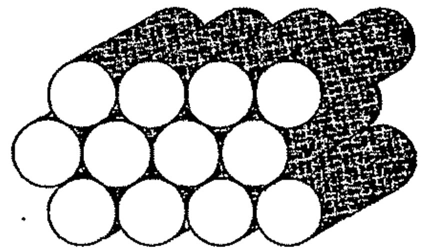
Rectangular



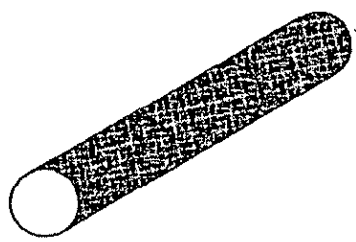
Rhomboid



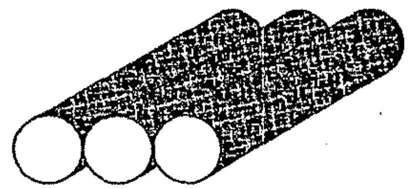
Trapezoid



Nested



Tubular



Flat Pack

Appendix 3

Final Drawings

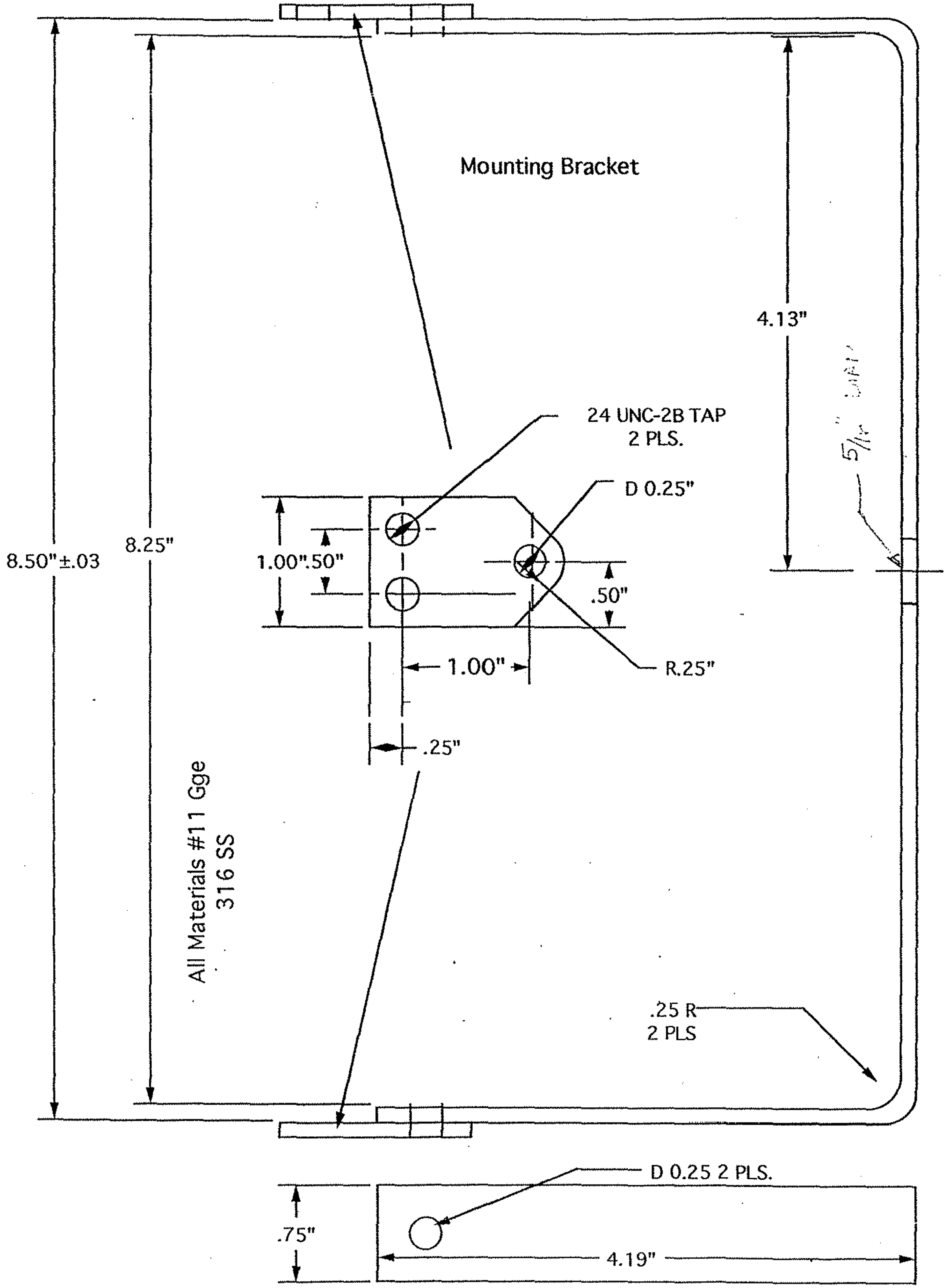


FIGURE 1: ARRAY MOUNT

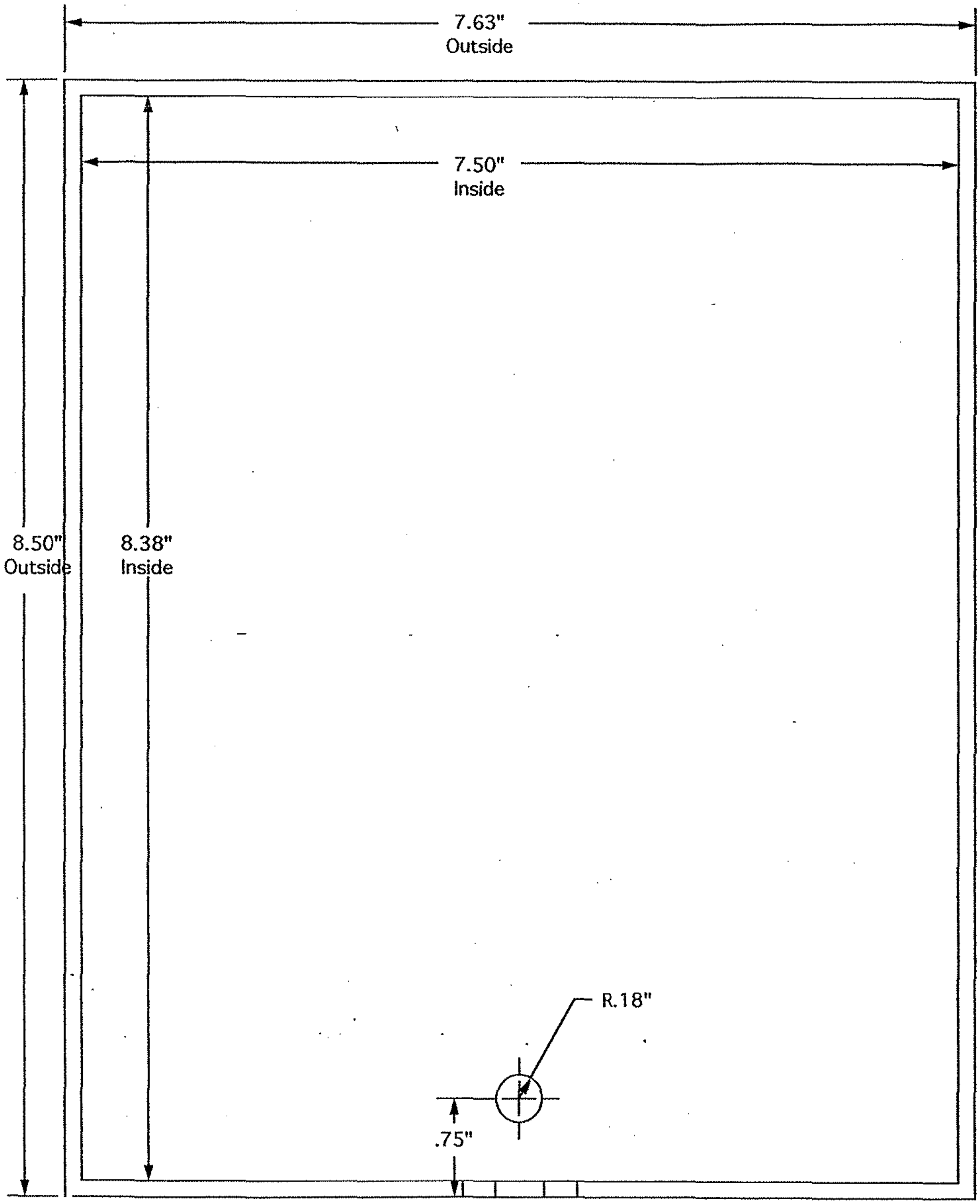


FIG2: Array Holder
Material 1/16" thick

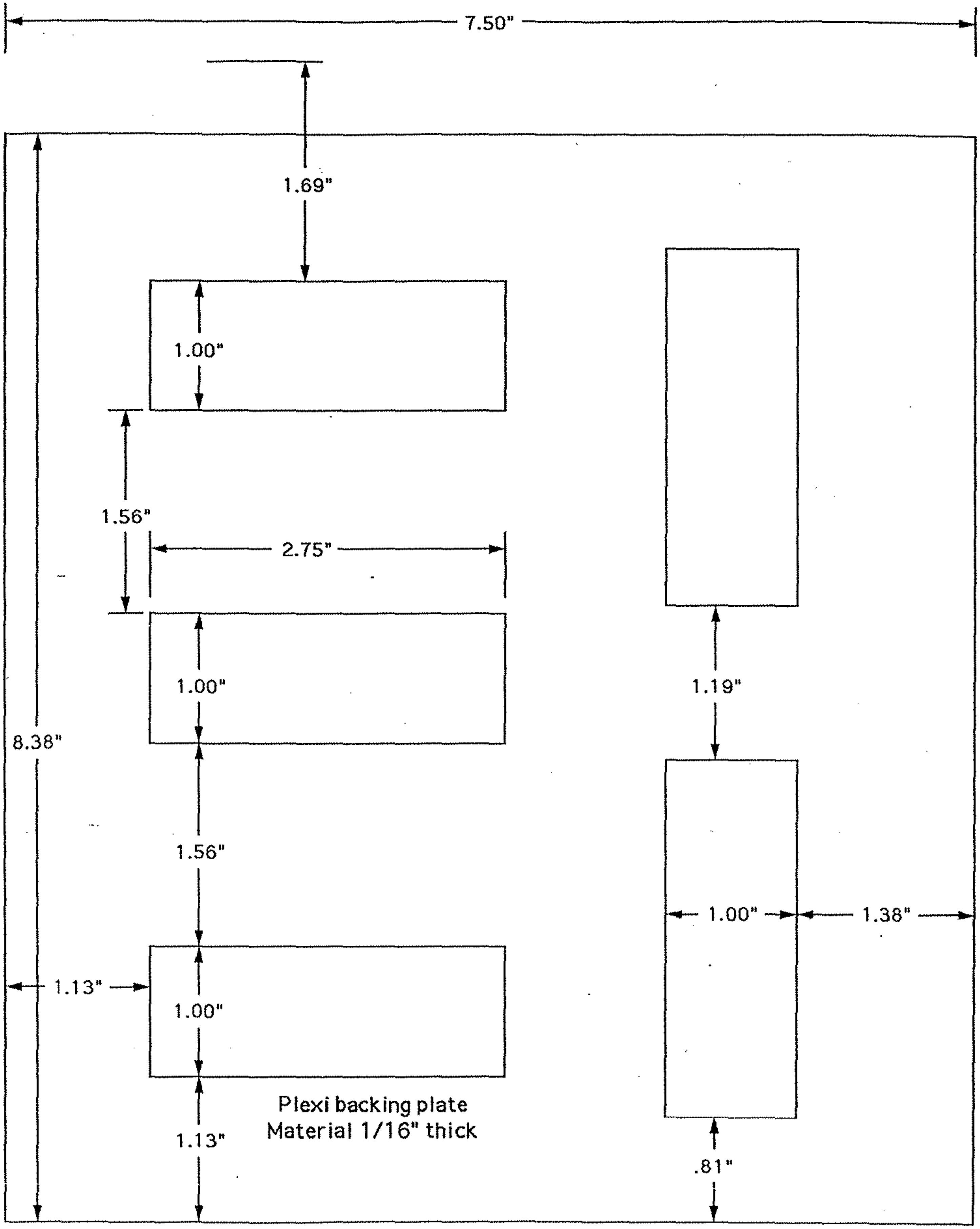


FIG 3: BACKING PLATE

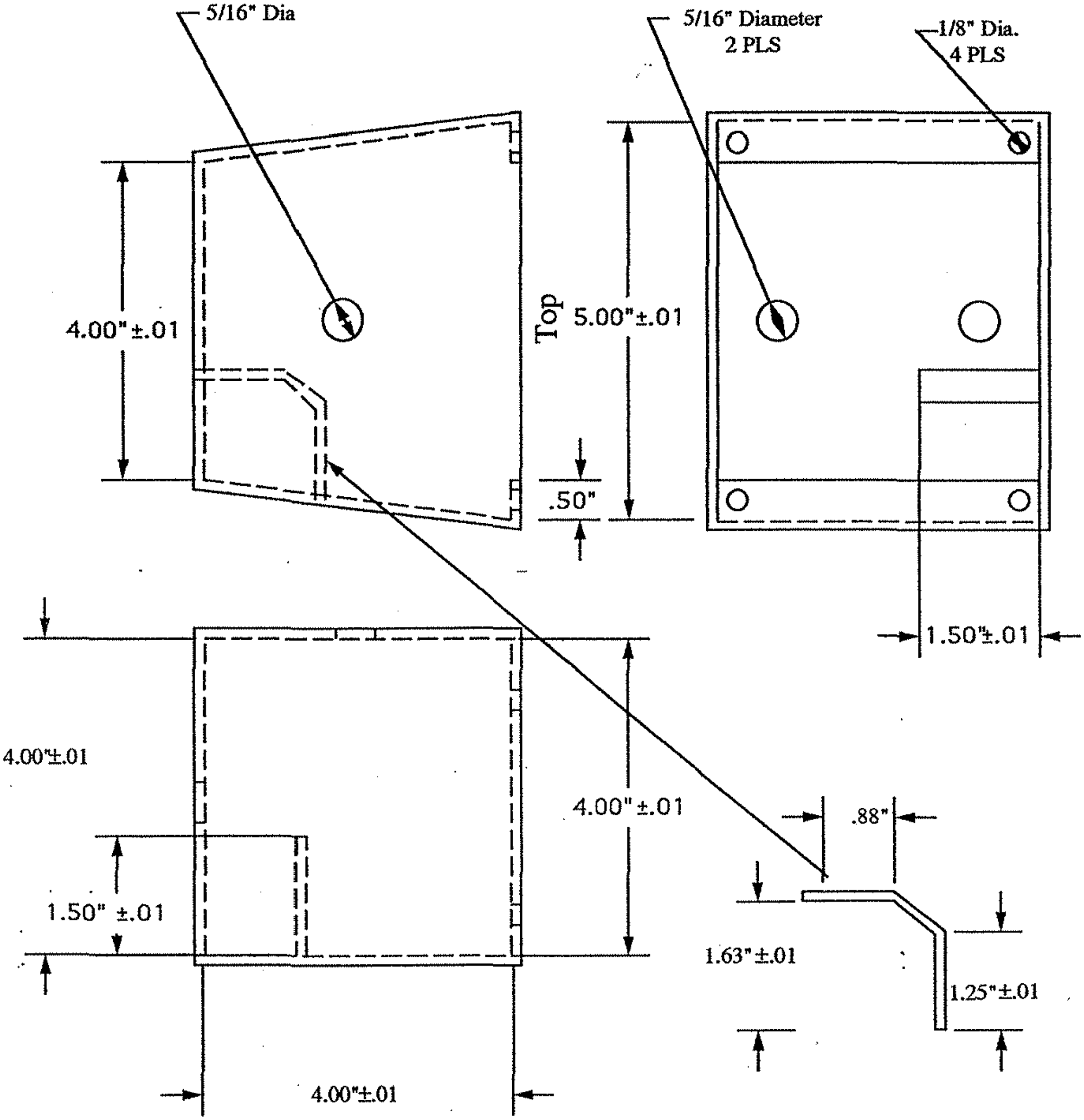
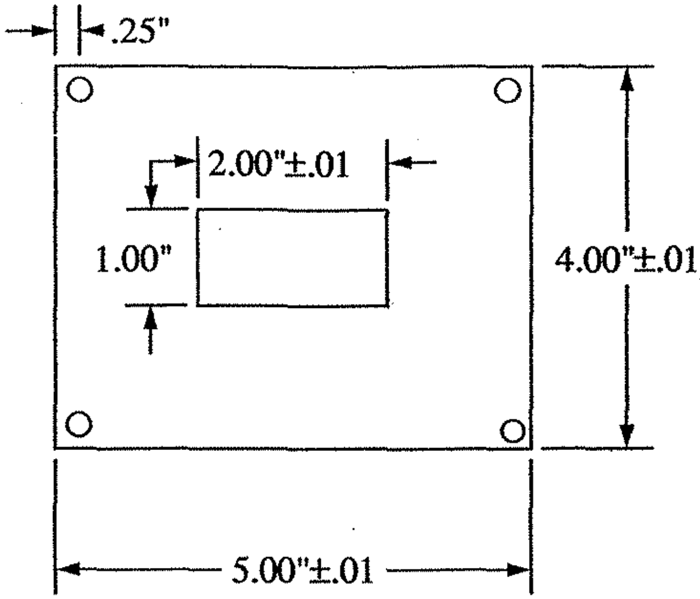
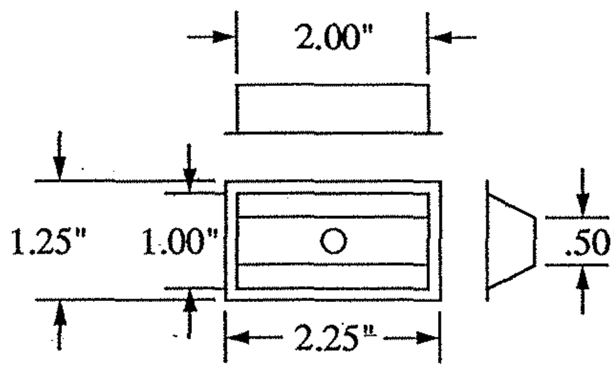


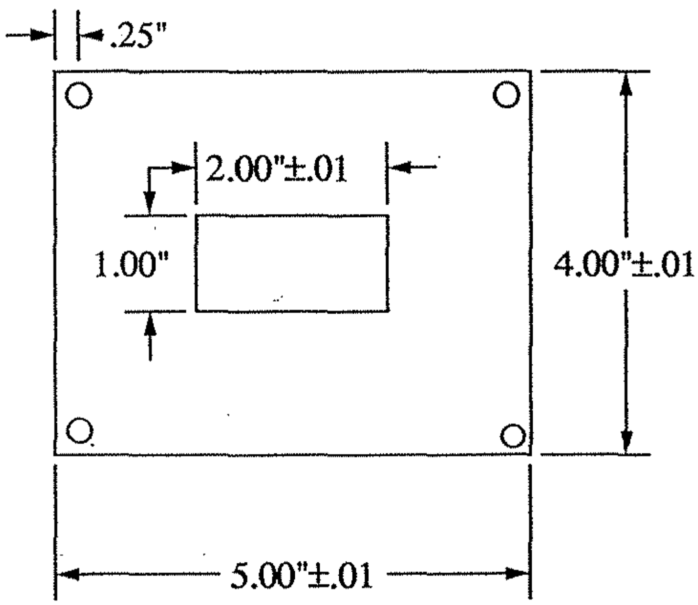
FIG 4: Light Fixture Plans : FRAME
1/2 Scale



Cover



Light Reflector



Backing Plate

FIG 5: Light Fixture Plans, COVER
1/2 Scale

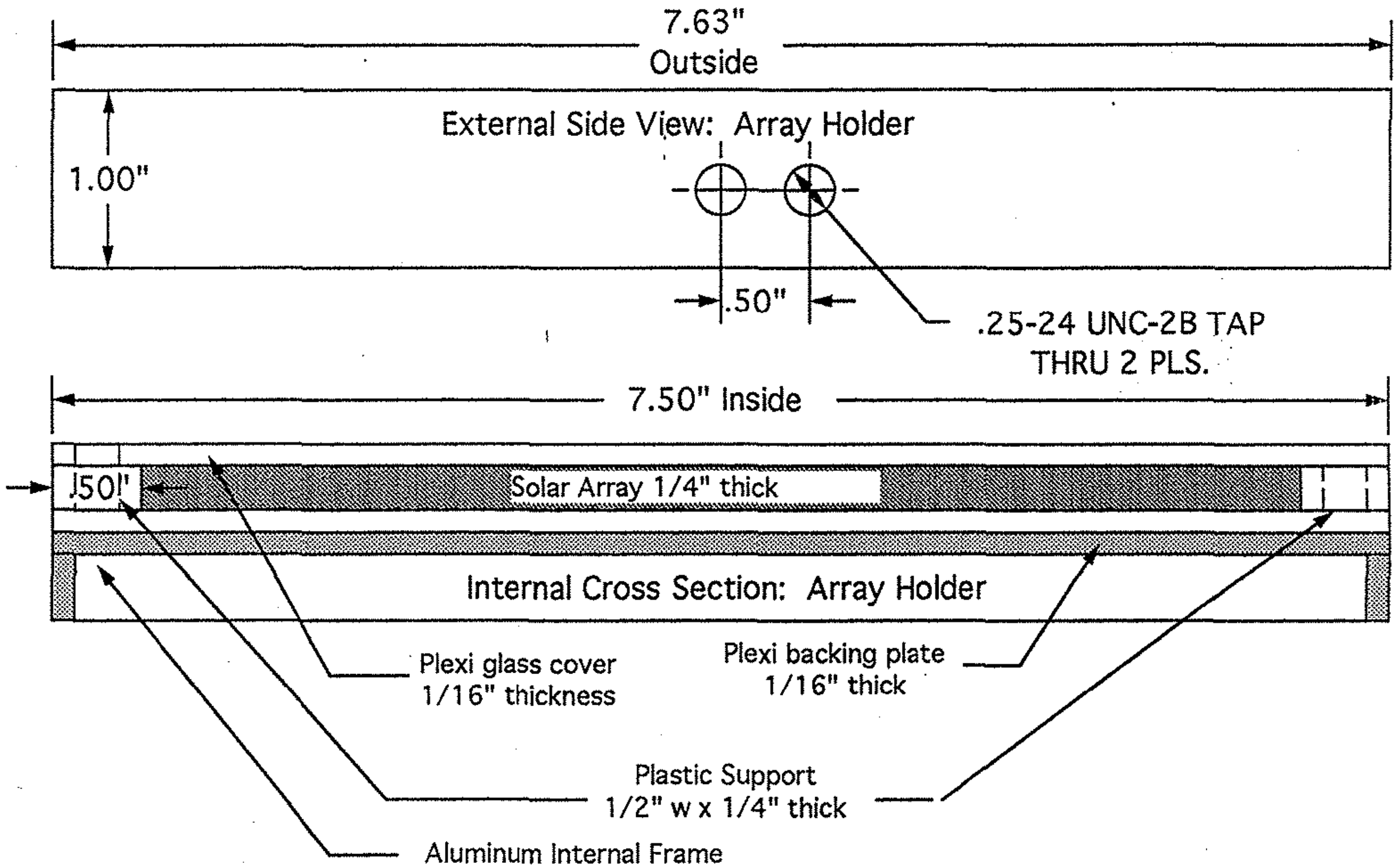


FIG 6: ARRAY CROSS SECTION

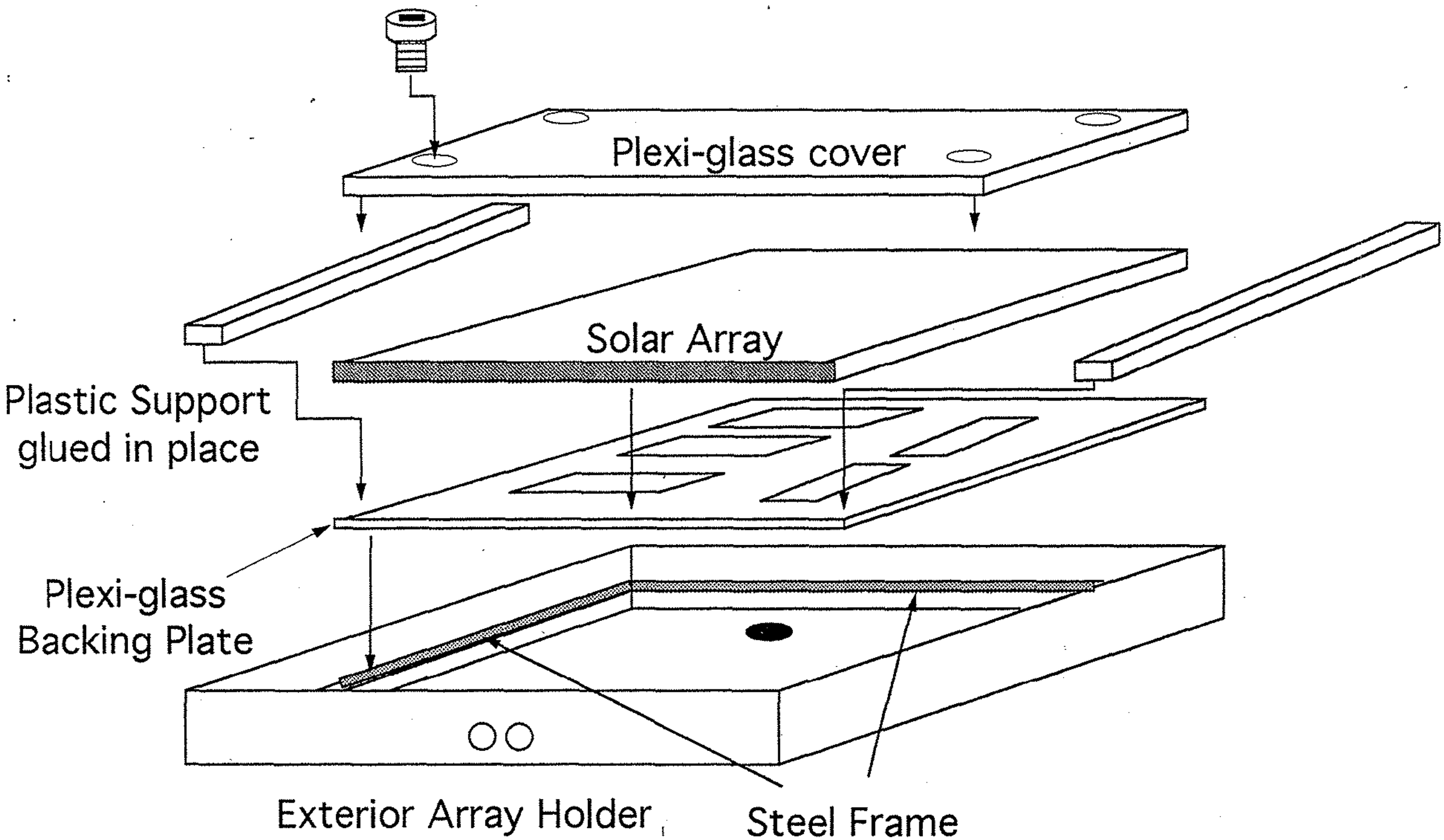


FIG7: Assembly Drawing: Array Holder

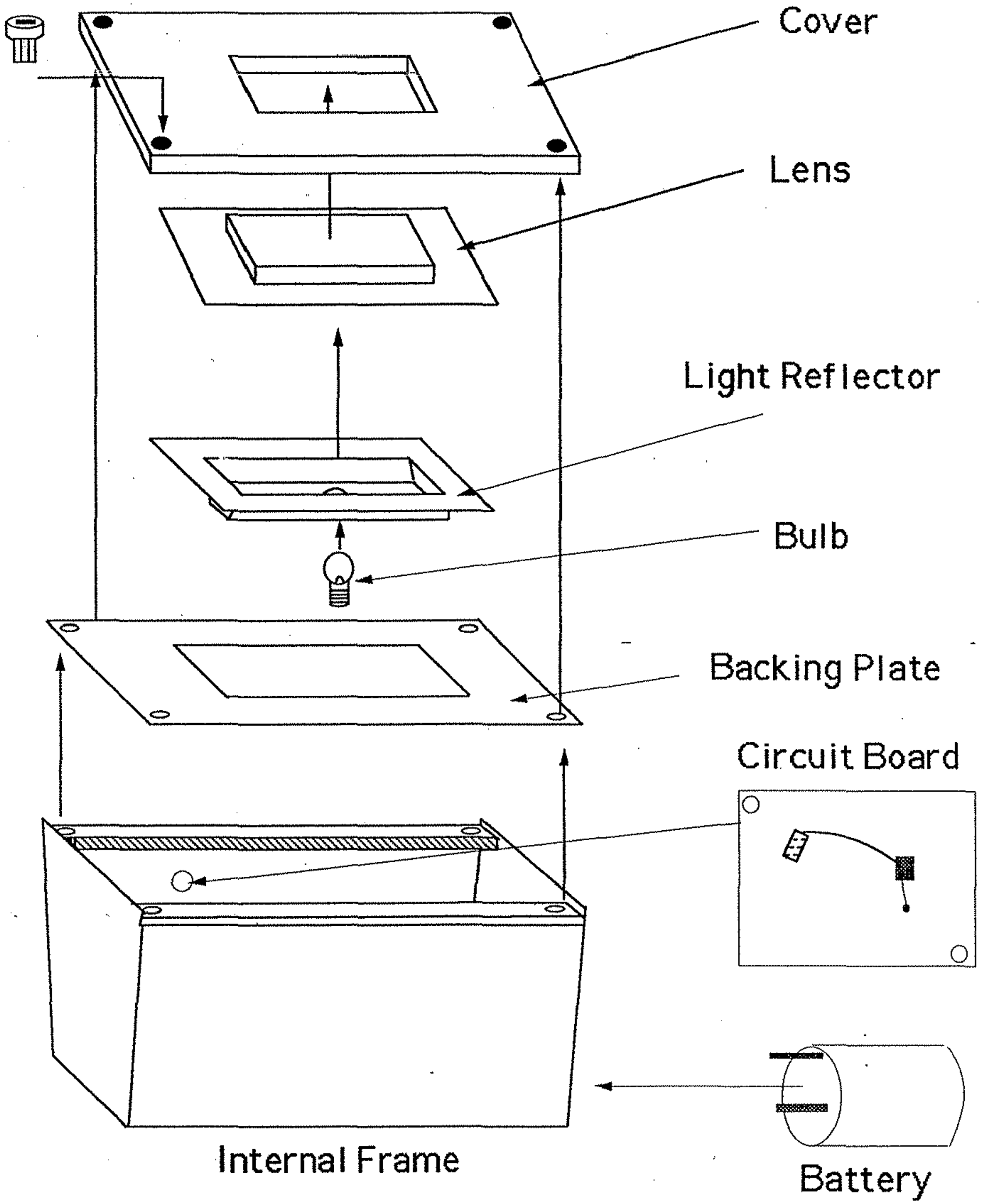


FIGURE 8:
Assembly Drawing: Light Fixture

Appendix 4

Safety Concerns: Batteries

Underwriters Laboratories, Inc. (UL), with the assistance of Industry Advisory Councils, develops Standards for Safety for the safe operation of products that could present the hazard of electric shock, fire, chemical causality, or other nature. Specifically covering battery chargers are:

UL 1236-Electric Battery Chargers
UL 1310-Direct Plug-In Chargers

Others that deal with batteries as only one of several components are:

UL 45-Portable Tools and Equipment
UL 924-Emergency Lighting and Power Equipment

The National Fire Protection Association publishes the National Electrical Code (NEC) a standard used extensively to judge construction materials, components and methods.

Other Potential Battery Hazards:

-In the event that a cell should leak, protective gloves should be worn when handling the cell to prevent chemical burns from the electrolyte. First aid treatment requires that the caustic material be diluted with water.

-Electrical Shock can occur with more than 30 cells in series which presents a voltage of 43.5 volts when on charge. This voltage is considered the threshold of electrical shock capability for direct currents. At the most, our system will consist of 6.5 volts.

-Proper disposal of batteries: do not mutilate batteries, do not dispose of sealed batteries in a fire, as they may burst explosively and release toxic fumes.

-Ventilation for the battery must be taken into consideration in the design of any battery compartment to prevent from trapping hydrogen and oxygen gases which under some circumstances, when mixed with air, may explode when ignited.

-Thorough instructions on proper use, storage, and charging practices should be provided to the user. A periodic test procedure is advisable as well as a warning that will unmistakably indicate when the battery is no longer functional.

WARNINGS:

- **Do Not incinerate or mutilate batteries; may burst or release toxic chemicals.**
- **Do Not Short Circuit batteries; may cause burns.**

Appendix 5

Supplies and Cost Breakdown

Supplies and Cost Breakdown

The following list of supplies used in the construction of our prototype.

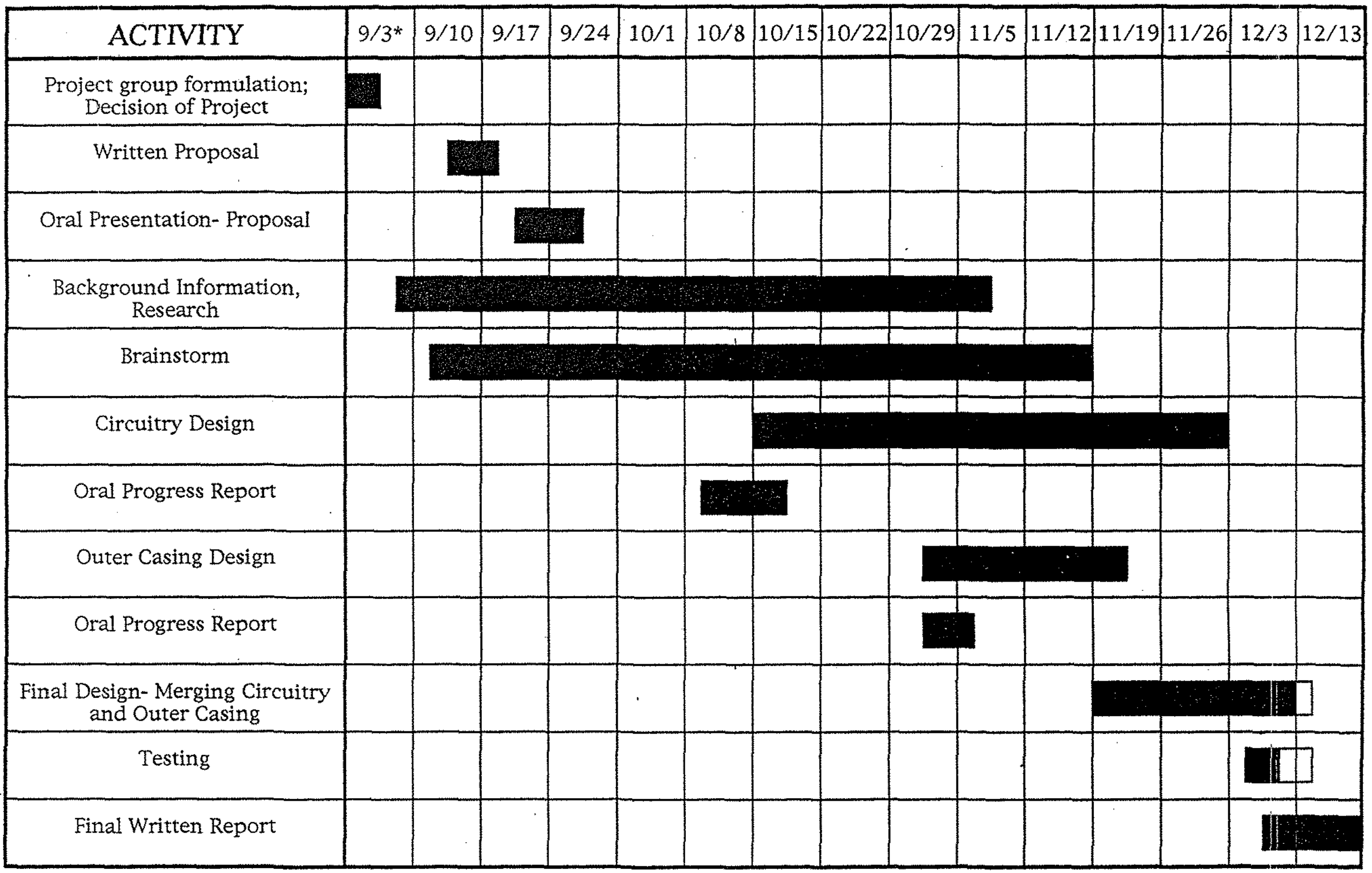
Notice that some items have been donated, but an approximate price is listed.

Item	Cost
2-volt, 100 mA light bulb	$ 2.00
Rechargeable Battery (donated)	$10.00
Wiring/ Electrical	$ 6.75
Solar Cells (5)	$21.25
Material	
St. Steel Construction	$25.00
Labor	
Engineering Dept. Machine Shop ($31.50/hr.) $409.50 (Donation)	
Sealing Material	$ 5.00
Plastic Material (covers)	$ 5.00
Telephone Calls	$15.00
Transportation (gas to Ames, IA)	$30.00
	+
Totals	$529.50

Appendix 6

Gantt Chart

PROJECT SCHEDULE: <u>Group B:</u> Solar Powered Highway Delineator System



Updated: December 12, 1993

* 9/10 = week of 9/3 through 9/10

Appendix 7

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Appendix 8

Contacts and Acknowledgments

We would like to extend our thanks to The Iowa Department of Transportation for their interest and support of this project. Without their interest and funding, this project may not have been possible.

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- Professor T.F. Smith for his insight information, and support.
- Any other faculty members who provided insight, encouragement, and support.
- Mike Davis of Gates Energy Products for his support and donation of batteries.
- Dean Macken and employees of Engineering Machine Shop for fabrication of design.
- The Mechanical Engineering Project Class for your support of our project and helpful suggestions throughout the semester. It was through your support and suggestions that enabled us to design a delineator that will hopefully increase safety on the road at night.