Applied Innovative Technologies, Inc.

Developing useful and unique products that have lasting performance

NightStar's Technical Design: Questions and Answers

NightStar represents the most reliable hand held light source ever made. NightStar's unique and fascinating design has inspired people to ask the following excellent questions.

1. **Can light output be made brighter by replacing the LED with an incandescent bulb?**
An incandescent bulb is highly inefficient and requires significantly more energy than an LED. The capacitor in NightStar can only power a filament light bulb for several seconds but can power an LED for several minutes. An incandescent bulb also has a lifetime of approximately 500 hours and is extremely fragile. Quite frequently, a bulb will break before it burns out. By comparison, the LED used in NightStar will operate for more than 100,000 hours and is nearly unbreakable. Therefore, for reasons of energy efficiency and reliability, an LED is the logical choice for the NightStar emergency light.

2. **Can adding more LEDs increase the light output?**
The ETS (Energy Transformation System) Cell within NightStar can power more than one LED, and with each LED added, the light output will increase. However, power consumption will also increase with each LED added to the system. Consequently, the duration of light output obtained from a fully charged capacitor will diminish, thereby requiring NightStar to be shaken more frequently. Adding more LEDs will also increase the cost of the device. Therefore, one LED was chosen in order to maximize the time between recharge cycles and to minimize the unit cost.

3. **Why was a lens chosen for the output window?**
Placing a specially designed acrylic lens at the appropriate point effectively collects and images the light output from the LED. The lens also serves as a window, and due to its design it is able to withstand tremendous pressure, shock and hazardous chemical environments. Therefore, with a single component, optimum light output and durability are obtained.

4. **Can a larger capacitor be used to increase the time of useful light output?**
Several capacitors were studied during the development of NightStar. NightStar currently uses a 1-Farad, 5.5V capacitor. A capacitor with an energy storage capability 3 times greater than this is also available (3.3-Farad, 5.5V). A 3.3-Farad capacitor would increase the useful light output time to more than 15 minutes. However, it would require 3 times longer to fully recharge. A 3.3-Farad cap is also much larger and would have greatly impacted the size of NightStar. We concluded that a smaller flashlight requiring 30 seconds of shaking to obtain 5 minutes of useful light would be more marketable than a larger light that would require 1 ½ minutes of shaking.

5. **Can batteries be included in the design to allow for a longer, brighter light output?**
A battery will power the LED in NightStar for several hours at its' maximum light output (the same light output obtained when the capacitor is fully charged and the light is first turned on). Additionally, the ETS Cell in NightStar can be used to charge a battery as well as a capacitor. However, the energy storage capability of a battery is many times greater than the capacitor used in NightStar. Consequently, it would require thousands of shakes to recharge a battery using an ETS Cell. Also, the lifetime of a rechargeable battery is rather limited when compared to a capacitor. The capacitor in NightStar can be recharged several hundred thousand times. Rechargeable batteries, such as NiCd, NiMH, and LiIon, can only be charged and discharged several hundred times. * Batteries also fail to work effectively in cold environments; capacitors do not suffer this problem. Finally, batteries are both costly and considered a hazardous material. Batteries that depend on chemical reactions not only pose a danger to the environment but are also corrosive and can destroy a flashlight. Adding a battery to NightStar would therefore weaken its design and marketability. One of the most unique and significant features of NightStar is that it will never need replacement parts or maintenance. The components within NightStar and their integrated design yield a product that can be relied upon to light the way, anytime, anywhere.

   *The rated lifetime of these devices is determined by the number of cycles it takes to reach 80% of their rated energy storage capacity. The user will still get additional cycles after the rated life however. The diminished storage capacity means less useful battery life

6. **How is the charging magnet reflected at either end of the flashlight?**
Neodymium magnets are mounted at both ends of the flashlight and are oriented to repel the charging magnet. The magnetic repulsion recoil system smoothly decelerates and accelerates the charging magnet back through the coil without loss in mechanical energy. Consequently, the loss of energy due to friction is extremely small and is only the result of the cylindrically shaped nickel-plated charging magnet sliding through a polished tube. Kinetic energy is

therefore efficiently coupled into electrical energy with almost no degradation to the system. Lasting performance is obtained with this design.

7. Why is the housing made from plastic?

Most importantly, any type of metallic housing will prevent the charging magnet from moving effectively through the coil. This is due to free electron eddy currents being set up in the metal housing when the charging magnet travels through the barrel. Consequently, magnetic fields generated by the eddy currents in the housing oppose the magnetic field of the charging magnet. The faster the charging magnet tries to move, the stronger the opposing fields will be in the housing. Therefore, the charging magnet will never pass through the coil with enough speed to charge the energy storage capacitor. The plastic housing is superior to a metal housing in several other ways as well. The material and manufacturing costs of plastic are far less expensive then aluminum (aluminum is a likely choice for a metal housing). Additionally, NightStar's plastic housing will never rust or oxidize and weighs less then an aluminum housing that would provide the same amount of crush resistance. The plastic used in NightStar is an alloy of polycarbonate and ABS (Clear NightStar however, is made of pure polycarbonate; polycarbonate/ABS is not available in clear). Polycarbonate/ABS was chosen for two reasons. First, it is difficult to break even at cold temperatures, and second, it is unaffected by salt water, mild acids, alcohol, methanol, ammonia based cleaners and is corrosive resistant when briefly exposed to petroleum products such as gasoline, oil and grease. Clear NightStar's however, are not as chemical-resistant against petroleum products but have slightly higher impact strength.

8. What are the magnets made of and how are they magnetized?

The magnet is an anisotropic sintered ceramic containing neodymium, iron and boron (NdFeB). The anisotropic nature of the material (meaning that it has properties that differ according to the direction of the measurement) is due to the tetragonal crystalline structure of the NdFeB molecule. The magnetic dipole associated with each crystal lattice site aligns itself along a well-defined axis within the bulk material. As a consequence of its molecular magnetic structure, the material is remarkable in two ways. First, it possesses a high-density magnetic field because of the alignment uniformity of the magnetic dipoles, and second, it will hold this field for an extremely long time even when orientated for repulsion with another magnet or subjected to extreme temperatures. All of the magnets in NightStar were initially slugs or disks of ceramic NdFeB. They were then plated with either nickel (the charging magnet and the switch activation magnet) or zinc plated (the repulsion magnets mounted on either end of the light). The plating, which gives the magnets a metallic look, serves to protect the magnet from corrosion, chipping and scratching. Nickel is a standard, tough, smooth coating and zinc protects the magnet and provides an excellent bonding surface. The zinc plated repulsion magnets, which are pressed and epoxied into pockets will therefore only come out when the flashlight is totally destroyed. Finally, the coated ceramic pieces are placed in a torroid chamber that converts electricity into an extremely high strength magnetic field. The ceramic pieces become magnetized within a few seconds and will remain so for thousands of years.

9. How does the switch work?

Inside the switch is a small magnet. As the switch is moved forward the magnet slides over and activates a reed switch mounted on the circuit board inside the flashlight. When the reed switch is activated (or closed) energy in the capacitor flows through the LED. This design feature has several advantages over conventional mechanical switches used in other flashlights. The most significant advantage is reliability; the simple sliding plastic switch can not corrode or wear out and the reed switch is rated at over 1 million cycles. In comparison, mechanical push button or toggle switches have components that corrode and springs that fatigue after limited on/off cycles. Another key advantage to NightStar's switch design is that it does not require a watertight seal sense the magnet on the outside is able to active the reed switch through the plastic housing.

10. Can NightStar's beam penetrate through smoke?

Experiments conducted in the "Zero Visibility Smoke Chamber" at the firefighting training and test facility in Loveland, Colorado demonstrated that NightStar's blue-white beam, though not useful as an illumination source, is quite effective as an emergency signaling light and can be seen through smoke over 20 feet away. By comparison, the high power lights typically used by firefighters penetrate only a few feet through smoke while simultaneously back scattering off the smoke particles and blinding the searcher. NightStar's beam appears as a blue-white shaft of light that extends out 3 to 4 feet from the searcher and has no blinding backscatter problems.

(All tests were made possible by the tremendous support of the Loveland Fire Department. Smoke in the chamber was produced by burning hay and couch fabric material.)

11. Is a pacemaker sensitive to the magnetic field that surrounds NightStar?

NightStar can affect a pacemaker's normal mode of operation. If the heart rate of a person with a pacemaker drops below a preset value (typically 85 beats per minute), an internal sensor monitoring the person's heart rate activates the pacemaker. A pacemaker will not send electrical signals to a person's heart unless their heart rate drops below the preset value. In order to test whether a pacemaker is operating properly, a reed switch is built into the unit so that an external magnet held up to the patient's chest will close the reed switch and deactivate the internal heart rate sensor. When this happens, the pacemaker turns on and begins sending electrical signals to the heart at the preset value. Pacemakers are typically tested once or twice per year in specially equipped hospitals. If a pacemaker begins sending signals to the heart at a rate of 85 beats per minute and the heart is already beating at a greater rate, an arrhythmia condition can be triggered. The possibility of this occurring is extremely rare; less than 1 percent of the people with pacemakers would be susceptible to this condition, and those that are, are in many cases already bed ridden. A magnetic field with a strength of 90 gauss brought within 1.5 inches (40 cm) of a pacemaker will close the reed switch. The magnet in NightStar has a surface field strength of over 5200 gauss. Consequently, in order to avoid turning on a pacemaker, NightStar should be held no closer than 2 inches (5 cm) from the chest. At this distance the field strength has dropped to approximately 30 gauss. A cautionary statement regarding the effect NightStar has on pacemakers is printed on the product packaging and instruction booklet. (This information was obtained from a phone conversation with one of the largest manufacturers of pacemakers in the U.S.)

12. Can NightStar be made smaller or larger?

The ETS Cell that transforms kinetic energy into light can be scaled up and down in size. A smaller NightStar prototype has been designed. It is 20% smaller, requires approximately 90 seconds of shaking to become fully charged and has a useful light output that lasts 10 minutes. When resources permit, the smaller prototype model will be released as a product.