The Birth of a New Lamp System

By Henry Schneiker
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To a caver, light is everything. I learned this simple truth a long time ago when I first started caving. You see, the sun never rises in a cave. Darkness is forever. Thus began my quest for a reliable cave light.

Like so many people of that era, I used a carbide lamp as my primary light source, a flashlight as my secondary light source and candles as my tertiary light source. The theory was that you carried enough carbide and spare parts so you could fix any problem with the carbide lamp. The flashlight would allow you to get things fixed or find your way out in a pinch. The candles would give you light and heat for an extended emergency stay. As it turns out, the flashlight was unreliable after a couple of trips and you could never get the candles lit -- so you learned how to repair your carbide lamp in the dark.

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A carbide lamp is actually a very good light when it comes down to it. It provides a nearly optimal beam of light when fitted with a clean parabolic reflector and set to produce a large flame. The characteristics that make this beam of light so much better than the beam of a conventional electric headlamp is that the beam is very smooth and tapers slowly from the bright center to the dimmer edges. It makes it easy to see the big picture. You are less likely to miss your footing because the path from your feet to where you are looking is always smoothly lit.

Carbide lamps are also nearly indestructible. You can bang them against rocks or drop them down a pit and they keep right on working. That's not to say they won't go out after you drop one. But if it does, you just recover the lamp from where it lies and light it up again.

Now I must admit, carbide lamps need to be fed regularly, sometimes get indigestion and I've never been able to get them to work reliably under water. And I don't think I'll ever forget the smell of burning flesh--usually somebody elses. But all things considered, a good carbide lamp is a reliable companion.

Time to go Electric?

In the mid 70's I started heading off to distant lands on expedition caving trips. Deep caves. Wet caves. Long rope drops through water falls. A carbide lamp takes only 6 seconds to burn through a rope with your weight on it. And like I said, I never did find a way to get a carbide lamp to work under water. Electric lights were beginning to look like a good option.

My first electric headlamp was a Justrite® electric headlamp mounted to an aluminum plate with a battery holder on either side. The battery holders were left exposed for easy cleaning. The whole assembly clipped on to my climbing helmet using a standard 3/4" flat hook. I chose the new lithium/sulfur dioxide technology

to power the lamp because of their high energy density and reduced weight. These batteries were rather expensive (compared to bulk carbide) but when I looked at the actual hourly operating cost I discovered that battery expenses were significantly less than food or transportation expenses for a typical weekend. In the grand scheme of things, it wasn't an issue.

Little did I know when I designed my first headlamp that death was lurking in the shadows. The headlamp tried to kill me twice on its first trip to Mexico. The single incandescent bulb failed at exactly the wrong time, leaving me in darkness on exposed climbs on both occasions. I also discovered after a week that the battery contacts, while easy to get to and clean, needed to be sanded before every trip because of the corrosion. Later, on another trip with the lamp in New Hampshire, I encountered the real problem with leaving everything exposed. Upon arriving back at camp, while starting to unload the car, there came a hissing sound accompanied with a cloud of white vapors emerging from my duffle bag. I grabbed the duffle and heaved it away from the car, knowing exactly what the problem was (the manufacturer had clearly explained this issue in their literature). One of the batteries had been shorted on the loose carabiners, causing it to overheat and vent. Not dangerous under the circumstances but smelly. That was the last time that headlamp was ever used.

My second electric headlamp consisted of two Coast Guard rated flashlight heads mounted to an aluminum plate with the battery compartment mounted underneath. A rotary lamp cord switch was attached to each flashlight head and all wiring was routed so no shorts were possible. I left the switches exposed for easy cleaning, figuring I could just exercise them under water to clean out the mud and dirt. The rest of the lamp was completely sealed. Dual filaments, dual lamp housings, dual switches. The only thing that was not redundant was the battery. But since lithium batteries are so reliable I figured that was not necessary. This arrangement worked well except the exposed switches were smashed to bits rather rapidly. They still worked if you held them together while operating them (to turn them on or off). The basic arrangement was good but the switching needed improvement.

I should take a moment for those who are not familiar with caving to point out that caves are very hard on equipment. When it comes to physical abuse, mud and water, caving will destroy more equipment per hour of use then almost any other endeavor you care to name -- including the military. If you want to find out if your gear is tough, take it underground.

While at the Pittsfield NSS convention that summer, I was discussing my third design for a headlamp with a young lady who asked a lot of detailed questions. She wanted one for herself but I was not interested in making more than a couple for my own use. Much to my surprise, the next afternoon, she came up to me with a stack of checks and asked me to make 15 of them. I had told her I figured it would cost about $50 to build one (we are talking 1979 dollars). I was amazed that there were that many people at convention who would put so much money down for my unbuilt lamp. So I accepted the stack of checks and built the lamps. They were completely sealed with nothing breakable exposed. In 18 years I have never heard of one of the lamps failing. Lost, yes, failed, no.

The third headlamp design had dual lamps, dual switches and was fully sealed

Perhaps a Different Technology

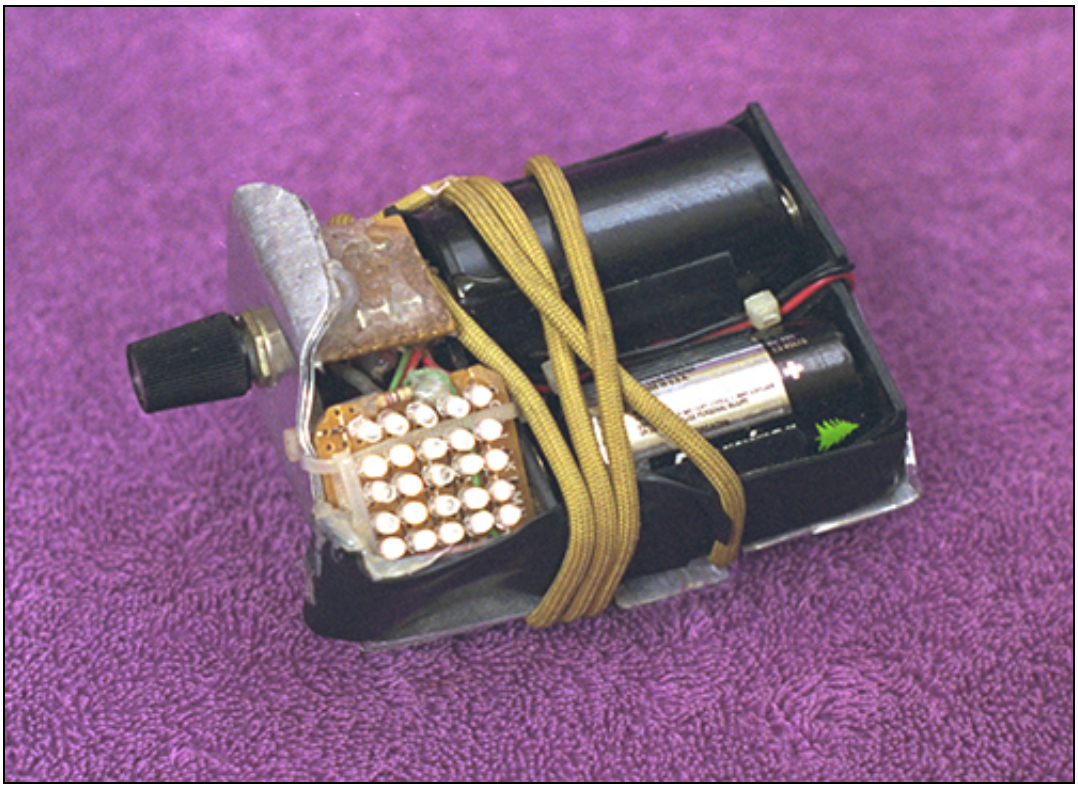
Even as good as the third headlamp design was, I was still not happy. So I kept trying different technologies. I tried various types of incandescent bulbs. Zenon flash tubes. Various kinds of arc lamps. Florescent lamps. And various kinds of LEDs. Of these, the florescent lamps produced the most satisfactory results. The problem with florescent lamps turned out to be a reflector problem. The solution was to mount a 4" florescent lamp in a plastic driving light housing with the circuitry in back of the lamp. Worked great and produced a nice walking beam. But it was bulky and I didn't think it was rugged enough. The various LEDs I tried were all monochromatic and proved disappointing. Mixed colors were an improvement but still did not produce the results I wanted.

Then in 1997 I heard about a new white LED. From several different sources. One person had actually seen one in operation. Months later I was finally able to find a source and get one. These things were pricey -- $8 each. But they did work. The technology was actually a blue LED that included phosphorescent materials to absorb the blue light and emit green, yellow and red, thus producing white light. And the color quality was quite acceptable. The efficiency was not bad either. Expensive but rugged.

It was clear that a single white LED was not going to produce enough light to be a main source of light. So how many would it take? One company was talking about releasing a light with 10 LEDs in an array. But would 10 be enough? I did a few experiments and figured it would take at least 25. Can you say sticker shock?

The first proof of concept was 25 LEDs soldered together on a piece of proto board and taped to the end of a lithium battery. Worked great. But more light was needed and I needed a higher voltage to get to maximum

output. So I taped on another battery and a couple of resistors. I used an alligator clip as a switch and had 3 different brightness levels. The results were great. Just to make sure, everything was packaged up with some bent aluminum and mounted on my helmet. Right from the first cave trip it was an obvious success. I also tried it out on search and rescue missions and on a few long night hikes. It was a hit.



The proof-of-concept lamp saw significant usage. Second battery (lower right) and resistor pack (upper left) substituted for a real power supply during initial testing

My first price estimate for a completed lamp was $200. I'd need circuitry, a sealed switch and a lot more stuff than lamp number 3 used. I figured I could find 25 people to buy one. Hmmm. Not really enough to justify all that work but I really wanted several for myself. After a lot more thought I was able to identify an estimated 1000 unit sales over 5 years. That was probably enough to justify doing a real design.

So I began. It took months. And months. Lots and lots of details. If you have never taken a product from concept to production you will have a difficult time understanding the level of effort to accomplish this task. I wanted to fix all those things from other lamps that had irritated me over the years. This lamp would be rugged, light weight, have good battery contacts, be fully sealed, have three brightness levels: very bright, normal and a forever mode so there was no excuse to sit in the dark. There would be no changing batteries in the dark. And no sudden darkness.

When I started pricing things out I came to the horrible realization that I couldn't even buy the parts for the price I wanted to sell the lamps for. So the price had to go up. More importantly, the parts cost had to come down. That took more research and design changes. More volume needed. Suffice it to say that after a lot of effort I was able to make the equations work. Remember the company I mentioned earlier who was going to do the lamp using the array of 10 LEDs? Two years later it has never come to market. Now I understand why.

So at long last I have my dream lamp. I no longer have to worry about having enough light. The only spare part I carry is an additional battery. For extended trips I carry multiple batteries. For total redundancy I simply carry a second Action Light™. With reliability this high you no longer need the third source of light -- but carry one anyway.

The completed Action Light was a replacement for a carbide headlamp. It would run for 12 hours on the high setting before stepping down to the medium setting