Modern Lights for Cave Diving
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Cave divers separate lighting into two categories, primary and backup lighting. The primary light is of higher output then the backup lights. The primary light should have adequate burn time for any planned dive and the backup lights should be of significant brightness to suffice for exiting a cave in the event of a primary light failure. The backup lights combined burn time should be twice the duration of any planned dive.

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The evolution of primary lighting follows the innovations in everyday lighting. Lighting in general has advanced almost as fast as personal computers. The early primary lights utilized tungsten filament bulbs and the light output was yellow meaning low Kelvin temperature. Because caves are without any light at all the yellow color was not good enough for the cave diver. We measure all light output by comparison to daylight consciously or unconsciously. To raise the color temperature we applied more voltage and we would power a six volt bulb with 7.2 volts or a 12 volt bulb with 14.4 volts operating at voltages of 10 to 15% higher than the bulb was rated for. By overdriving the bulbs we got white light, more suitable for cave diving. The down side of this was the overdrive shortens the life of the bulb and failure rates were high. This led to some cave divers carrying two primary lights and so it was not uncommon to see cave divers carry four to five lights on a dive due to high failure rates brought on by the overdrive. The next generations of bulbs were gas filled bulbs, with halogen being the most popular because it was available in higher wattages then the krypton and xenon style bulbs. The halogen bulbs are higher in color temperature and inexpensive and became the mainstay of primary lighting until the turn of the century. The 21st century brought in new technology of high intensity discharge (HID). HID lights are more expensive than halogen, but the light output and increased burn times offset the cost.

For the past eight years, HID has been the standard for cave diving primary lights. The first HID lights were bulky as we adapted the electronics from the medical lighting and/or automotive market. Welch Allyn was the first company to develop an affordable and compact bulb and ballast combination, the 10 watt HID. The innovative design changed cave diving primary lights

forever. The technology was developed specifically for the diving and bicycle markets. The light output of a 10W HID light is equivalent to a 50W halogen light because of the higher color temperature. A typical 50W halogen bulb is 3000 degrees Kelvin and a 10W HID is 6000 degrees Kelvin. Higher wattage HID lights don't increase in color temperature but rather increase the lumens (a measure of the total light output of the lamp) for more available light.

Wattage is primarily a measurement of power consumption (amperage load) so now we have lights that consumed only 20% of the power and battery technology could change as well because of decreased demands on amperage needs.

The first batteries used were lead acid batteries, in some applications wet cell lead acid batteries such as motorcycle batteries. When looking for higher color temperatures nickel cadmium (NiCd) batteries were used. The output to weight ratio made them ideal for primary canister lights. The cell voltage of 1.2 volts per cell made it easy to bundle them together to over drive the halogen light bulbs by the needed 10 to 15 percent. We used two types of nickel-cadmium batteries, the wet cells which were highly corrosive or the dry cells that are common today.

The wet cells were unique in that they could be field charged off a car battery. A 15 amp pack could be charged in a matter of minutes, when properly ventilated (don't try this today). State-of-the-art in their era, nickel-cadmium batteries had memory problems so the batteries needed routine maintenance. The halogen bulbs did not agree with the overdrive like the tungsten bulbs, so lead acid batteries came back into style and this made a winning combination for years.

The early nickel-metal hydride (NiMH) batteries could not handle high discharge rates. They were popular for laptop computers and cell phones but could not handle a 5 amp draw needed to power a 50W halogen bulb. A 10W HID bulb only draws 1 amp, which is well within the discharge rate of the nickel-metal batteries. This discharge rate to weight ratio of the battery made for a perfect combination with the 10W HID bulb. Now lithium- ion batteries have evolved into cells capable of high discharge rates so lighting companies are incorporating rechargeable lithium-ion batteries. All battery types have trade-offs in performance, maintenance, shelf life, charging parameters, heat dissipation, ~~etc~~ and cost. This is why certain battery types are matched to bulbs and application.

The combined evolution of light bulbs and battery technology for primary canister lights has led to a drastic reduction in the weight of a primary light. The battery canister for a 50W halogen light was typically fourteen inches tall and five inches in diameter and weighed fifteen pounds. It only burned for two and a half hours. Today's primary light is approximately eight inches tall by two and one half inches in diameter and weighs less than three pounds. It has a burn time of over four hours. It's like comparing eight track tapes to compact disc (if you remember).

Today, light emitting diode (LED) lighting is the future for cave diving. The main objection to LED in the past was the lack of light penetration. However, due to improved parabolic reflectors, we are now able to get light penetration equal to a 10W HID. LED lighting is ideal for the cave diving environment because they can handle frequent on-off cycling, unlike HID lights that are sensitive to short-striking. Being made of solid state components, LEDs are difficult to damage by external shock; an issue we have always had with HIDs and halogen lighting if they are dropped or struck by another piece of gear. LEDs have a long life, usually around 50,000 hours whereas HID lights typically average 1,000 hours of life. LED is still a growing technology, yet it is changing so rapidly that soon it will rival HID lighting when used as a primary cave light.

Back up Lights

The evolution of back up lights is primarily limited to the bulb technology. Early back up lights were bigger than some of the primary lights today. Since back up lights are seldom used the most economical and efficient batteries are standard alkaline batteries. Do not be misled by the new max power or long lasting advertisements for batteries. The longer lasting batteries state on the packaging the longer lasting power is designed for cameras. These batteries are designed to have a low power drain. The bulbs in back up lights use much more energy than that depending on the bulb wattage; you will be very disappointed with the results of the higher priced long lasting batteries so stay with the normal alkaline batteries for back up lights. Since these are back up lights we never plan to use them so it is better to replace batteries on a routine schedule to ensure they are fresh when called upon to get you out of a cave. There are lithium batteries and rechargeable batteries but I do not recommend either as back up light options. The lithium ion batteries have a long shelf life, yet are expensive to replace and probably not changed out as often as they should be for a back up light. Rechargeable batteries must be cycled and the burn time checked for consistency. The maintenance alone is enough to not make it a suitable for back up lights. The back up lights should be reliable and if there is any question about burn time, replace the batteries.

The innovation for back up lights is in the bulbs. The gas filled bulbs are brighter and now LED bulbs are becoming the choice for back up lights. The lower power consumption of LED lights can give burn times of up to fifty hours on four AA batteries.

The key is to select the right combination for your type of diving, brightness for the first back up used when a primary failure occurs and then something with long burn time when you are on the first back up light and down to two lights. Some divers carry more than the minimum two back up lights because the smaller sizes make it easy to carry a selection of back up lights with different features for various environments or situations. With all the variations in reflectors, bulbs and LED combinations I recommend checking back up lights under different conditions to see what is best for you. Make sure your combination has adequate combined burn times or carry an additional light to get the needed total burn time. Replace the batteries often to ensure you have the burn time when you need it.