speleonics 18 July 1992

volume V number 2

DEPTH OF TRANSMITTER (y-axis)

ANGLE OF FIELD FROM VERTICAL (DEG.)

DISTANCE FROM GROUND ZERO

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CONTENTS

SPELEONICS is published quarterly (sometimes irregularly) by the Communication and Electronics Section of the National Speleological Society (NSS). Primary interests include cave radio, underground communication and instrumentation, cave-rescue communications, cave lighting, and cave-related applications of amateur radio. NSS membership is not required for newsletter subscription. Section membership, which includes four issues of SPELEONICS, is $6.00 in USA/Canada/Mexico, $8 overseas. Send subscriptions to section treasurer Joe Giddens at the address below (make checks payable to SPELEONICS.) If you have a ham-radio callsign or NSS membership number, please include them when subscribing.

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Editorship rotates among the officers. Volunteers are encouraged to guest-edit or produce an issue. A technical session, followed by election of officers, is held annually during the NSS Convention.

Complimentary copies of SPELEONICS go to NSS offices and sections, the U.S. Bureau of Mines, U.S. Geological Survey, and the Longwave Club of America.

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COVER

This version of the familiar cave-radio depth graph was plotted by Dr. Robert F. Blakely of the Indiana Geological Survey, using a Hewlett-Packard desktop computer. It relates depth to vertical angle of the transmiter's magnetic field at different horizontal distances from its epicenter ("ground zero"). Any distance units may be used. Bill Mixon and Dick Blenz originally published the curves in 1964.

LETTER

Ian Drummond's notes on fluorescent lights in SPELEONICS 17 caught my attention. I've lately been experimenting with a belly-mounted fluorescent lamp for limited use in walking passages only. Helmet-mounted fluorescent lamps don't hold great interest for me at this point in their development, since 1) they tend to be relatively fragile and I bump my head, 2) the diffuse light is only good for near-field viewing, and 3) I want a spotlight on my head for distance viewing.

The fluorescent light is much better as a belly or chest light, since you don't have to worry about aiming it. The advantage here is the visibility of shadows in walking passage -- the head-mounted lamp tends to obscure shadows on the floor very badly; the belly-mounted lamp brings them right out. This a function of having the lamp above or below the plane of vision. Try it with a flashlight; it's simple enough to demonstrate.

Such a lamp, I believe, should be considered as an addition to the headlamp rather than a replacement for it.

Experiments in March at Ft. Stanton Cave (NM) convinced me that such a system is useful in certain parts of certain caves. CRF is going back there this July 4 weekend, and I'm planning to experiment further.

Also efficacious are fluorescent lanterns for fixed work. We were digging leads in a (very!) small cave in the Sandia Mountains a couple of summers ago, and an Eveready(tm) fluorescent lantern made work much easier-- when the lantern was extinguished, it was instantly missed, even though the diggers were using headlamps. I plan to try them at Big Manhole Cave if that operation resumes.

Note that this work all has been done in environmentally fairly benign New Mexico caves. I can get away with using off-the-shelf fluorescent lamps with retrofitted clips and brackets. This work may not generalize to extremely wet and muddy caves. Not yet, at least.

There'll be more information after the next series of experiments.

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Announcement:

TUNNEL DETECTION SYMPOSIUM

The fourth tunnel detection symposium on subsurface exploration technology will be held April 26-29, 1993 in Golden, Colorado. It is sponsored by the Combat Engineering Directorate, U.S. Army Belvoir Reearch, Development and Engineering Center, in cooperation with the Colorado School of Mines. Contributor Bruce Bevan says that these symposia grew out of an interest in detecting North Korean tunnels beneath the DMZ. For more information contact:

Office of Special Programs and Continuing Education
Colorado School of Mines
Golden, 80401
(303) 273-3321
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ALKALINE PRIMARY-CELL FAILURE MODE

Douglas Strait NSS 9707

I recently experienced an alkaline cell failure via a mechanism previously unknown to me. The cell experiencing this failure was one of the 4 cells within an Eveready Energizer(tm) #529 6V lantern battery. Fortuitously, this battery had been tested before use in such a way as to preclude ascribing this failure to previous abuse or gross manufacturing defect. Prior to using alkaline cells or batteries, I routinely test them under load. My standard test for 6V lantern batteries or sets of 4 "D" cells is to apply a load of 0.7A (with the battery at room temperature) and to measure the terminal voltage after 1 minute. I have found this to be an effective means of detecting batteries containing weak or defective cells. The battery containing the cell which later failed was initially tested via this method and determined to be good. The battery was used under normal caving conditions for 7 hours during which performance was satisfactory and approximately 40% of the nominal capacity was removed. The battery was subsequently stored in a refrigerator for 6 months with the exception of 3 or 4 occasions when it was transported in my truck on caving trips but not used. Total estimated distance of truck transportation subsequent to the initial 40% discharge was in the range of 5000-6000 miles. I happened to use this battery to test a light and noted that the terminal voltage under load was markedly lower than expected based upon the discharge history of the battery. Because I was curious about this, I decided to investigate further. I removed the sheet-metal cover from the battery to permit access to the individual cells. I measured the individual cell voltages under load and found 3 to have voltages consistent with the battery discharge history and the fourth cell to have a much lower voltage. None of the cells exhibited leakage or signs of physical abuse. I then disassembled the "bad" cell and one of the "good" cells. The visual appearance of the interior of the two cells was essentially identical with the notable exception that the anode current collector which consists of a piece of brass sheet metal was silvery in appearance in the "good" cell and darkened in the "bad" cell. I knew from previous cell autopsies that the anode current collector normally retains its silvery appearance even in completely discharged cells. I decided it was time to seek professional help. I contacted the Eveready Southeastern Region Engineering Assistance Office and eventually was connected with someone who probably knew the answers to my questions. As a relevant aside, in 20 years of dealing with technical representatives of countless products, I have never encountered an individual who was more actively unhelpful than this person I spoke with. Some of the information presented here are my inferences based upon this conversation. When given the opportunity, the Eveready technical representative declined to confirm or deny most of my inferences. When I described what I had done and what I had found, the first question I was asked was whether the battery had been subjected to shock or vibration. Believing that 5000-6000 miles in the back of my pickup qualified, I responded - YES. The Eveready Tech Rep volunteered that there is a "rare" failure mode associated with shock and vibration consistent with my observations. He declined to characterize the relevant levels of shock/ vibration or the probabilities of failure. The more specific my questions became the less candor his answers contained. I managed to determine that the darkened anode current collector is an indicator of this failure mode. I also concluded that in the case of the Eveready cells (and presumably those of other manufacturers) the effort to reduce or eliminate mercury in these cells has significantly increased the occurrence of this "rare" failure mode.

What action is appropriate given the very limited information we have on this failure mode? I suggest the following:

1. Avoid subjecting your batteries to unnecessary shock and vibration.
2. Where high confidence in battery capacity is required such as when a single battery is to be taken on a long cave trip, test the battery immediately prior to use. As previously described, I test alkaline lantern batteries and sets of 4 "D" cells by measuring the terminal voltage 1 minute after application of a 0.7 amp load. For my uses, approximate remaining capacity is given by the formula %capacity = (V-3.00)/3.00. This formula at best gives a fair approximation of capacity. You will find that new batteries will typically yield a capacity figure of 90-95%. I use an LM317T voltage regulator configured as a constant-current sink for the 0.7 amp load. This test should be performed at 68 to 77°F [20 - 25°C] for best results.

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INCANDESCENT LAMP PARAMETER VARIATION WITH VOLTAGE

Douglas Strait NSS 9707

Most readers are probably familiar with the way in which incandescent lamp parameters (current, life, light output, efficiency, etc.) vary in response to applied voltage. Most lamp manufacturers publish this information as a table or graph. These tabular or graphical data are derived from a set of equations that relate the parameter of interest to the applied voltage, via voltage raised to an exponent. These exponents are based upon a composite of various designs of lamps. Typical exponents used are 1.8 for efficiency (efficiency varies as voltage raised to the 1.8 power), 3.5 for light output (light output varies as voltage raised to the 3.5 power), 0.54 for current (current varies as voltage raised to the 0.54 power), and 12 for lamp life (lamp life varies inversely as voltage raised to the 12 power).

I have long been intrigued by a footnote that some manufacturers include with these data. The General Electric Miniature lamp catalog is typical in stating "...(these data) are approximate only between 95% and 110% of rated voltage...will not apply to lamps with lives in excess of 5000 hours or to halogen-cycle lamps".

While lamps with design lives in excess of 5000 hours are of little interest to cavers, halogen-cycle lamps as well as operation outside of the 95%-110% of design are relevant. To satisfy my curiosity, I contacted the General Electric incandescent lamp guru. According to him, these formulas are good approximations for voltage variations far beyond the 95%-110% of rated range and also apply to halogen-cycle lamps provided that the lamp envelope temperature remains above the minimum required for the halogen cycle to operate.

I performed an experiment to determine the applicable exponent for variation of lamp life with voltage when operating far above design voltage. The lamp selected was the PR-13 which is an argon-filled miniature flange based bulb (flashlight style) with design ratings of 4.8V/0.50A/15 hours. A large quantity from the same production lot was procured. The lamps were tested under stationary conditions using direct current and base down positioning. Applied voltage was held to within ±0.01V of the test value. Test voltages were 4.80V (100% rated), 5.80V (120.8% rated), and 6.00V (125% rated). Test sample lot sizes were 6, 4, and 9 respectively. The derived life exponent for the increase from 100% to 120.8% of rated was 9.9 and the derived life exponent for the increase from 120.8% to 125% of rated was 10.4. While the sample sizes were fairly small, the data do suggest that at voltages well above rated, the life expectancy will be somewhat better than that predicted by the nominally-used exponent of 12 for life vs voltage.

SWITCHING VOLTAGE-REGULATORS FOR LEAD-ACID BATTERY CHARGERS

Douglas Strait NSS 9707 *

The traditional constant-voltage charger using a linear voltage-regulator IC is unbeatable for simplicity. All that's needed is a voltage divider and an IC such as the LM317 or LM350, and you're in business (see "Mine Lamp Charger" by Ray Cole, Speleonics 6 p.8). All linear voltage-regulator chargers have in common the characteristic that at least 1 amp must be input to the regulator for each amp delivered to the battery being charged. The energy associated with the difference between the source voltage and the battery charging voltage is dissipated as heat. This arrangement is fine for most applications.

For charging from car batteries or other energy-limited sources, the 1 amp in for 1 amp out characteristic of linear voltage- regulator chargers can be a liability: Using a linear voltage- regulator charger, a typical car battery in good condition can fully recharge two Wheat(tm)-style batteries (4V, ~15 AHr) at moderate temperatures without subsequent starting difficulty. Many of us in the real world, however, cave in the wintertime and only replace our car batteries when they will no longer start our vehicles. I have heard a number of reports of vehicles not starting after charging a single Wheat-style battery.

Switching voltage-regulators offer some relief from this problem. Instead of dissipating the energy associated with "excess voltage" as heat, switching regulators convert it to additional current delivered to the battery being charged. Efficiencies of 85% or better are attainable. A 2-cell lead-acid battery charged with current limited to a reasonable value will accept most of the charge at a terminal voltage in the range of 4.40 - 4.50 volts. This means that a switching regulator with an input voltage of 12.0 volts and an efficiency of 85% will deliver .85 X (12.0V/4.50V) = 2.27 amps to the battery being charged for each amp delivered from the 12 volt source. This is a big improvement over the 1-amp-for-1-amp of the linear voltage-regulator charger. The relative advantage of the switching-regulator charger becomes smaller for decreasing differential between the source voltage and the voltage required for charging.

A number of switching-regulator ICs have been introduced over the years. Some, such as the LM494, LM3524, and the LM3578 have low current capabilities and are best used as controllers to drive external power-transistors. By using any of the above ICs with a very low on-resistance P-channel MOSFET such as the IRF9Z30, efficiencies in the low 90%'s should be attainable. Other ICs such as the LH1605CK and the LM2579 incorporate BJT power transistors capable of delivering several amps at efficiencies of 70-80%.

I was finally moved to upgrade my vehicle charger from linear to switching-regulator technology when my favorite IC company introduced an 8-pin DIP switching regulator that has adjustable output, onboard current limiting, an externally-accessible voltage reference, and will deliver over 1 amp at an efficiency of 85%! This IC is the MAX758 by MAXIM. Their basic circuit from their datasheet is shown in Fig. 1.

As you can see, it is relatively simple. R2 and R3 determine the output voltage and are chosen per the formula $R2 = R3((V_{out}/1.23)-1)$ where R3 can be any resistance in the 10K to 1M range.
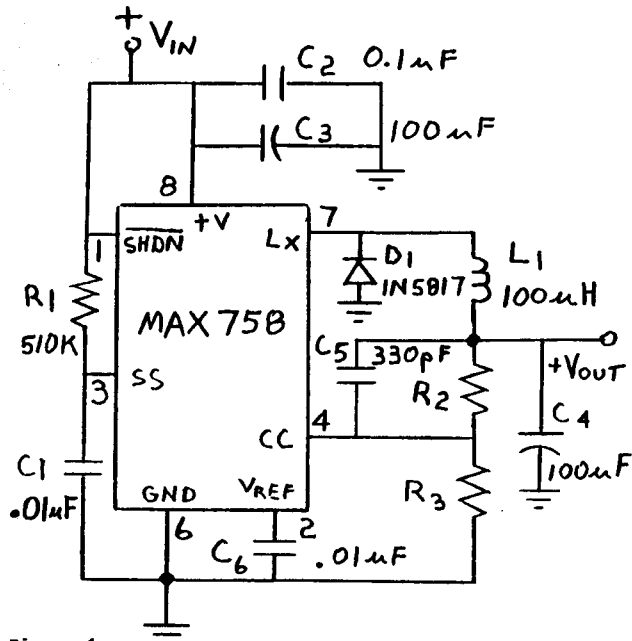
*   17 Pinehurst Dr.
    Caswell Beach, NC 28465
    (919) 278-9246

Figure 1.

BASIC STEPDOWN REGULATOR CKT.

I chose to elaborate on their design, as there are several additional things I want from a charger. These requirements are:

1. Indication that it is working.
2. Automatic shift from fast to float-charging voltage.
3. Indication that near-full charge has been attained.

The schematic in Fig. 2 is the version I chose to build.

Operation: The MAX758 is a pulse-width modulated stepdown regulator. Pin 4 is the feedback input and the IC regulates to maintain 1.23V at pin 4. The IC has onboard current limiting and the output voltage will sag as necessary to limit output to about 1.1 amp. The lower comparator of the LM393 and R7 perform the function of shifting between the fast and float charging voltages. When the lower comparator output (pin 7) is low, it causes R7 to modify the ratio of the divider formed by R2,3,4 and thus raises the level of V_{out} to the "fast" charge level. A low output of this comparator also causes the output of the upper comparator to go low, thus causing LED D2 to illuminate to indicate "fast" charge status. As the battery approaches full charge, charging current will taper off to a low value. When the voltage across R8 falls below the threshold established by the divider network consisting of R5 and R6 (R5 and R6 are dividing a 1.23V reference from pin 2 of the MAX758), the comparators will go high. R7 will no longer modify the ratio of the R2,3,4 divider, and the output voltage will fall to the "float" level. The "fast" charging LED, D2, will extinguish. R6 can be varied to vary the current threshold for the fast/float transition. The value of 820 ohms shown will cause the threshold to be about 0.1 amp. Raising the value of R6 will raise the current threshold.
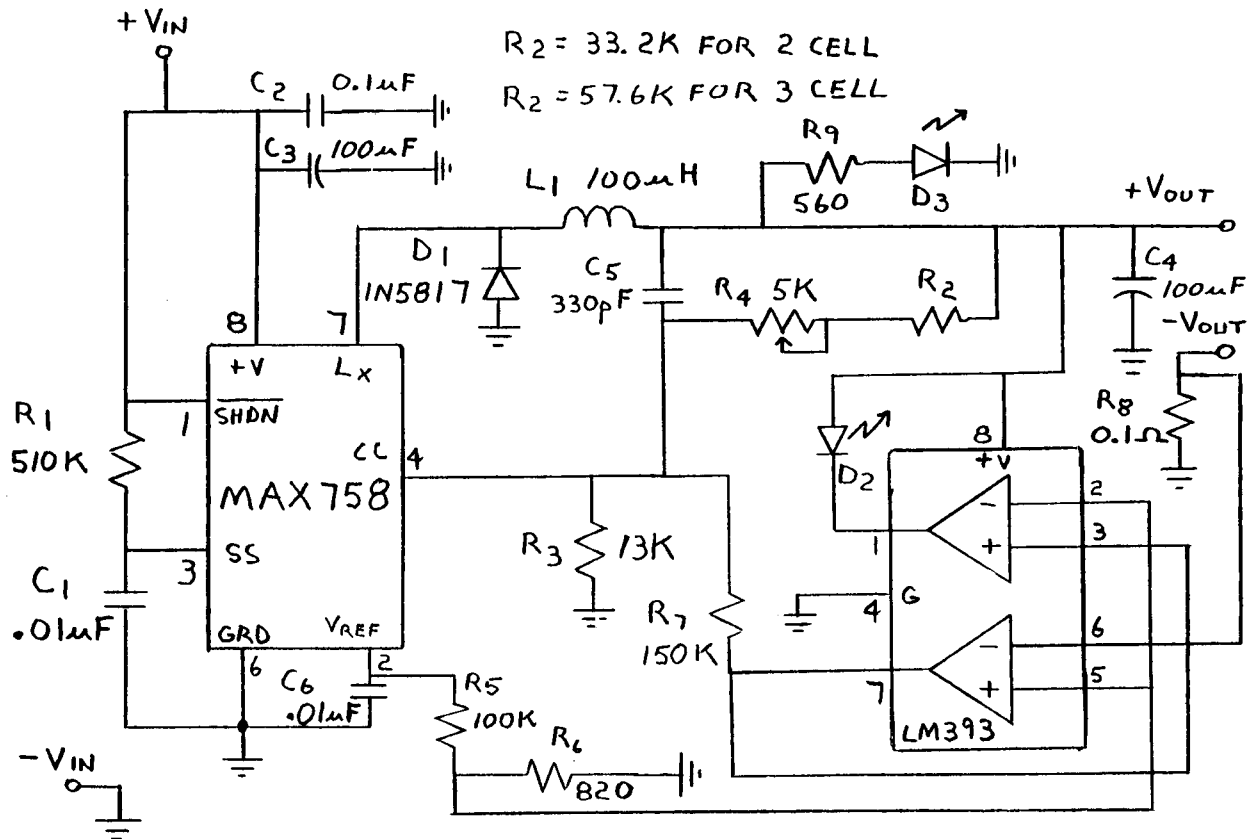
Figure 2.

CHARGER WITH ALL THE TRIMMINGS

What is an appropriate threshold? It must be higher than the value the battery-charging current tapers down to while on the "fast" charging voltage. I suggest setting the threshold no lower than C/100 where C is the capacity in AHr of the largest battery you anticipate charging. Wheat Lamp users may consider a threshold of around 0.2 amp. If you tend to have old and/or abused batteries you may wish to set the threshold somewhat above the C/100 minimum, as old/abused batteries tend to have higher residual currents. In general, when the fast-charging LED extinguishes, the battery will be very close to full charge, typically within 1 or 2%. Except at elevated temperatures, the battery could be left on float for weeks without harm. LED D3 is a pilot light which will illuminate either with input power supplied or with a battery connected to the output, thus it can be used to indicate both power availability and continuity from charger to battery under charge.

Perform initial checkout and adjustment as follows: Voltage values are indicated for both 2-cell and (3-cell) versions. With 12V applied to the input and no battery attached to the output, D2 should be extinguished and D3 illuminated. Adjust R4 to obtain 4.60 (6.90) volts at the output. Apply a load to the output slightly above your fast/float transition current. LED D3 should illuminate and the input voltage should rise to 4.80-4.90 (7.20-7.35) volts. Increase load and observe current limiting. Current limiting will typically occur in the range of 1.0-1.2 amps. Reduce load to a low value and observe transition to float voltage and that LED D3 extinguishes. Those who lack suitable equipment to use

as a variable load can improvise by using a fully-charged battery: Remove a few tenths of 1% of charge from the battery by running a light for a few minutes. Then connect your battery and ammeter to the charger. The charger will initially current-limit but charging current will soon taper off, allowing you to observe the "fast" charge voltage level and fast/float transition current. Note that the "fast" level will rise slightly with falling current due to the small voltage drop associated with R8.

Some general comments on construction and component selection: D1 (1N5817) is a Schottky diode. Do not substitute a non-Schottky type. L1 must have a DC current capability of at least 1.1 amp and the knee of its saturation curve should be >1.5 amp. Any value in the range of 80-120uH should be OK. I used 35 turns of 20-gauge [0.081cm dia.] wire wound on a 0.8" [2.03cm] dia. toroidal core which gave me 95uH and a saturation-curve knee at around 5 amps. Values of C1,2,3,4 are not very critical but C2 should be ceramic and >0.047uF and C1 should be >0.01uF. Locate C2 and C3 electrically close to the MAX758. The MAX758 is a CMOS device so the usual ESD precautions should be exercised during construction. If you use both 2 and 3-cell batteries as I do, you may wish to incorporate duplicate R2 and R4 along with a toggle switch to provide for charging either battery. Input and output connectors should be selected to suit your needs. I used a 5.5mm OD/2.5mm ID DC power plug for the input. Beware of plug/jack designs in which a momentary short is possible when you insert the plug. If the other end is already plugged into your car cigarette

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lighter socket it will blow the fuse serving the cigarette lighter.

Note that the design as presented is not reverse-polarity protected on either input or output. I did not require reverse-polarity protection, as both my input and output connector arrangements are polarized, thus precluding error. If your planned output-to-battery connection arrangement is not similarly foolproof and you are not one of those people who never make mistakes, you should consider incorporating reverse-polarity protection for the output. I do not recommend the usual blocking diode solution, as the forward drop thru the diode costs too much in terms of efficiency. The energy-efficient reverse-polarity protection solution is to fuse the output. If a battery is reverse-polarity connected, D_1 will be forward biased and the resulting large current will blow the protective fuse. Since the MAX758 will be in current limit most of the time, it will be working pretty hard. Special provision for heat sinking is probably not necessary, but to be on the safe side I glued a 1 square inch [2.54cm] piece of copper to the top of IC to act as a radiator. I assembled the whole works in a plastic box about the size of a pack of cigarettes.

Switching frequency is about 165 kHz. I tested for RFI by holding the charger (under load) near the loop antenna of a broadcast receiver. The charger could be heard on the AM band at distances of $\leq$ two feet [61cm].

How does it perform? My unit is set up to operate as either a 2-cell or 3-cell charger. Current limits at 1.1 amp. With a 12V input, efficiency while in current limit is 85% at 2-cell voltage and 86% at 3-cell voltage. Partial-load efficiencies are slightly better but this is not particularly relevant, as most of the total charging will occur while in current limit. The mean ratio of output to input current over a complete charge is 2.27 for 2-cell and 1.53 for 3-cell. For decreasing input voltage, an output of $\geq$1.0 amp at an output voltage $\geq$4.60 (6.90) volts can be maintained down to an input voltage of 8.7 volts for 2-cell and 11.7 volts for 3-cell.

While this design is not temperature compensated, performance should be adequate in the range of 15°F(-10C) to 80°F(27C). Above 80°F(27C) the specified voltages are a little high and thus the residual charging current may not fall low enough to trigger the fast/float transition. Those who anticipate routinely charging at temperatures >80°F(27C) should set the float voltage at 4.50 (6.75) which will lower the fast level by a similar amount. If this is done, the lower temperature limit of good performance will be around 32°F(0C). Those requiring performance over the widest possible temperature range should temperature-compensate the charging voltage. This is readily done by replacing a portion of R_2 with a negative-coefficient thermistor with appropriate value and slope.

Those who would like more bells and whistles might wish to include a 2-step charging level indicator. This is readily done by using a LM339 in place of the LM393. The LM339 is a quad comparator. By adding two additional resistors to the R_5/R_6 divider network, the additional two comparators could be used to drive LEDs indicating charging current levels of, say, 0.25 and 0.75 amp.

For a MAX758 datasheet:
Maxim Integrated Products
120 San Gabriel Dr.
Sunnyvale, CA 94086
(408) 737-7600

References:
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1. Cowlishaw, M.F. "The Characteristics and Use of Lead-Acid Cap Lamps." Transactions of the British Cave Research Association. v.1 no.4, December 1974 p199.

Automatic analog-regulator battery chargers:

2. Cole, Ray "Mine Lamp Charger" Speleonics 6 (v.1 #4, Fall 1986). (Reprint; article also appears in Caving Basics (NSS 1988) and numerous other publications.

3. ____ Sky and Telescope magazine, July 1989 p97.

4. Johnson, Don H. WB6MXD. "A Different Kind of Charger" 73 magazine, Aug. 1980 p115.

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H2 CATALYSIS FOR SEALED STROBES

John Ganter   NSS 22870

[Reprinted by author's permission from cavers' computer-mailing list, 20 June 1991.]

There have been reports in the caving literature of strobes and "weatherproof" cameras exploding (Caves & Caving 44 & 45, reprinted in SPELEONICS 14, also report in #15).

The culprit appears to be hydrogen (H_2) which evolves from alkaline and other "sealed" dry-cell batteries, particularly when they are discharged rapidly. The hydrogen is apparently ignited by sparking at switches or the high-voltage trigger circuit/electrode on the strobe.

Development work on high-powered and re-packaged strobes for caving led to further examination of this problem. I recalled that my PeliLite(tm) dive light has a collar around the reflector containing two small cylinders and the label, "Hydrogen absorber. Dry if wet." Efforts to obtain information from PeliLite were unsuccessful.

Inquiries were made to cavers by e-mail, with Frank Reid and Duke McMullen making suggestions for a chemical or catalytic solution. It was determined that MnO_2, while used within dry cells, would not work under ambient conditions.

Rane Curl then suggested a 1% platinum catalyst on alumina pellet substrate, in order to achieve what he termed "H_2-O_2 Recombination Catalysis."

A lengthy and expensive series of phone calls then took place. Eventually, a chemist at a large firm spoke on condition of anonymity. Platinum on alumina works in this application, even at 1/2%.

Provided that sufficient O_2 is present, all H_2 will be consumed and water produced. The chemist refused comment on the number of pellets required.

(Bill Stone has since pointed out that Tekna(tm) dive scooters have large platinum catalysts glued inside their housings to absorb H_2 from the vented lead-acid batteries)

The NSS Safety & Techniques Committee has obtained a quantity of the catalyst pellets. They will be used in a ratio of two pellets per C-cell or rough equivalent, with an adjacent desiccant pack to absorb the water produced. The first application is in the "TU-83," a re-packaged (waterproof) Vivitar(tm) 283 strobe presently being field tested.

The pellets are available free to any caver or diver who wants to experiment with them in strobes, dive lights, etc. We also have a large quantity of silica gel desiccant which is useful for camera equipment, film storage, electronics, etc.
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MORE ON HIGH-BRIGHTNESS LEDS

Douglas Strait   NSS 9707 *

Speleonics 15 contained a brief article by Jim McConkey on transparent-substrate AlGaAs red light-emitting diodes (LEDs). These are a significant advance in intensity and efficiency over earlier LED technologies. I read this article with interest but found that it lacked the information I regarded as most relevant, i.e., the luminous efficiency of these LEDs.

What are the luminous efficiencies of these LEDs? After reading this article I set out to answer this and other questions about these LEDs. What follows is a synopsis of what I learned from talking to various LED manufacturers, reviewing countless product datasheets, and testing a number of samples from four different manufacturers. I conclude with my opinion on possible uses of these LEDs.

First, a primer on units associated with light is in order; they are the source of much confusion. The total light (flux) emitted by a source is typically measured in lumens (lm) or Mean Spherical Candlepower (MSCP). 1 MSCP = 12.57 lumens. Intensity of a source is a measure of flux per unit solid angle and is measured in candelas (cd). 1 candela = 1 lumen/steradian. Note that the intensity of a source is independent of the distance from the source to the observer. To grasp the relationship between lumens and candelas, imagine a focusable flashlight: Changing the focus from a broad beam to a narrow beam does not change the light output (lumens) but does increase the intensity (candelas) within the beam as the same number of lumens are confined to less solid angle. Luminous efficiency is a measure of how much light (lumens) is obtained per unit of power (watts). The appropriate dimensions for luminous efficiency are lumens/watt or MSCP/watt. For reference, the following are the luminous efficiencies in lm/watt of commonly-used incandescent bulbs operated at their design voltages:

    PR-2   8.5
    PR-13   11.6
    425   11.6
    502   9.9

CAUTION: You may find the parameter Luminous Efficacy on some LED datasheets. Even though it has the same dimensions, lumens/watt, luminous efficacy is an entirely different parameter.

A table from Jim's article listing five Hewlett-Packard LEDs is reproduced here:

LED part#	Intensity (cd @ 20mA)	Viewing Angle (degrees)	Price	Price per cd
HLMP-8100	0.7	24	$.65	$.93
HLMP-8102	2	7	.80	.40
HLMP-8103	3	7	1.00	.33
HLMP-8104	4	7	3.50	.87
HLMP-8150	15	4	12.20	.81

Jim concludes his article with the statement, "The 8103 offers the most light for the buck". Is the true? Not according to the Hewlett-Packard product applications engineer that I spoke with. The truth is that all of these part numbers have (ignoring possible sample-to-sample variations) approximately equal light output and luminous efficiency! The intensity value is a peak value that usually (but not necessarily) occurs along the central axis of the LED package. The viewing angle is the angle within which the intensity is greater than 1/2 the peak intensity value. How much of the total light emitted falls within the viewing angle? It is highly variable. In the case of the HLMP-8100 (viewing angle = 24°), typically 19% of total emitted light falls within the specified viewing angle. For the HLMP-8103 (viewing angle = 7°) it is 26%. These values will show considerable variation among samples of the same part number.

Transparent-substrate AlGaAs red LEDs are offered by a number of manufacturers and are the most efficient technology currently available. What is the luminous efficiency? None of the datasheets I obtained answered this question. Of several LED manufacturers I contacted, I was unable to find someone who could answer the question authoritatively. I finally had success with Hewlett-Packard after five or six different calls (to HP). Luminous efficiency is approximately 8 lm/watt.

What about other colors? The most efficient yellow and green technology is about 1 order of magnitude less efficient and the most efficient blue technology is about 2 orders of magnitude less efficient. By 1993 new AlInGaP technology will be commercially offered by Hewlett-Packard in a 620nm reddish-orange and 590nm amber with luminous efficiencies of 5 lm/watt. Hand-built engineering samples of these are currently available for $10 each.

A number of LED samples from various manufacturers were obtained and tested. The following general observations were made.

1. Different models with similar viewing angles can have radically different intensity-distribution patterns.

2. While most LEDs tested came in T-1 3/4 packages, extremely narrow angle (<7°) LEDs have large packages, T-4 typical.

3. Narrow-angle LEDs ($\leq$15°) tend to have less-uniform intensity distribution patterns than wider-angle LEDs.

4. When used as a light source for caving, optimum viewing angle for handheld use is 20-35° and for helmet-mounted is 15-25°.

5. A subjective test of the "brightness" of equal "intensities" of white incandescent light and red, yellow, and green LED light was performed. My methodology here may be suspect but this is what I did: For each source I adjusted the intensity until I could just read black print on a white background at a fixed distance (like an eye test). I then did comparisons between the sources to assess subjective "brightness" among the various sources. The white incandescent light seemed "brightest" of the lot, the green and yellow less so but about equivalent to each other, and the red was least "bright" of all. I'm not sure what conclusions can be drawn from this observation.

6. LED datasheets all specify both a typical and maximum forward voltage at a specified current. I found no samples with forward voltage drops that varied significantly from the "typical" values. This observation is relevant to selecting power sources and ballasting

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     (919) 278-9246

arrangements. For AlGaAs red LEDs, forward voltage drop is about 1.6V at 1mA and increases logarithmically about .2V per decade up to ~50mA, beyond which the voltage rise steepens.

Some elaboration on the 8 lm/watt efficiency of these LEDs is in order. This value is for the LED itself. Typically, a ballast arrangement to regulate current to the LED is required. The power consumed by the ballast will reduce the overall system efficiency somewhat. While 8 lm/watt is somewhat inferior to the luminous efficiencies of the four incandescent lamps listed, the basis for comparison is far from equal. Three of the four incandescent lamps listed have design lives of 15 hours. All other things being equal, luminous efficiency of incandescent lamps decreases with increasing design life. According to reliability data provided for the HP 8100 series LEDs, if operated at their Absolute Maximum Rated current of 50mA at 25ºC the expected mean time before failure (MTBF) would be 1851000 hours (211 years). It can be inferred from their data and calculation methodology that if operated at double the Absolute Maximum Rated current (~2.3 times power) MTBF would be 480000 hours (55 years). The incandescent lamps listed would have MTBF measured in seconds if operated at 2.3 times design power. The four incandescent lamps listed have design powers ranging from 0.77 to 2.5 watts. The LEDs are capable of their 8 lm/watt efficiency down into the low mW range. Incandescents become relatively inefficient for design powers <0.1 watt, with design life held constant. For example, incandescent lamps 7931 and 7968 each have design lives of 500 hours and identical package design. The 7931 is rated at 1.35V X 0.06A = 81 mW with an efficiency of 1.6 lm/watt while the 7968 is rated at 2.50V X 0.20A = 500 mW with an efficiency of 5 lm/watt. LEDs when operated "on their own turf", i.e., at power levels <100mW, are far superior to incandescents in terms of luminous efficiency and life. A capability of LEDs not possessed by incandescent lamps is the ability to maintain a relatively high luminous efficiency thru a large power range. In contrast, the luminous efficiency of incandescents falls rapidly as power is reduced. The HP 8100 series maintain luminous efficiencies of >90% of the value @ 20mA thru a current range of 6 to 65 mA. LEDs have very short risetimes on the order of 100 nsec. Incandescents have risetimes on the order of 100-300 msec. Thus for flashing-beacon type service LEDs offer a great efficiency advantage when pulse durations are short.

Do LEDs have a role in providing "better caving thru electrical stuff"? Except for those who wish to make caving more challenging than it already is (how about a QRP Anvil Cave Rally, 10 mW or less?), LEDs will make no inroads for use as primary light sources. I see four possible applications. These are compass dial illuminator, flashing locator beacon, survey station sighting target, and low power/high reliability backup light source. The compass dial illuminator has been previously described elsewhere and will not be rehashed here other than to repeat the caveat that many LEDs have steel leadwires. Those interested in flashing locator beacons are referred to the National Semiconductor Special Purpose Linear Devices Databook: The LM3909 is an LED flasher/oscillator IC.

As a survey target, I tested an AND (company name) #AND120CR which has specifications of 1.28cd/35º at various current levels. As little as 1 mA provided a very visible target at 100'[~30m] distance. I constructed a target light using two alkaline "AA" cells and polycarbonate plastic as a case material. While two alkaline "AA" cells will provide about 2000 hours at 1 mA, I decided that such a small object would disappear thru a

hole in a cave pack or otherwise be misplaced long before 2000 hours runtime was accrued as a survey target. I chose to set the operating current at 10 mA which provides adequate illumination to also use the light for functions like primary light repair or changing carbide. Resulting dimensions of this light source are 4.20 x 1.36 x 0.75 inches [10.7 x 3.5 x 1.9cm]. The switchguard/lanyard attachment comprise 1.0" [2.5cm] of the total length of 4.20". Total weight is 81g [2.9 oz].

While developing criteria for a low power/high reliability backup light source I happened to read an account of a recent fatal caving accident which occurred in the Canadian Rockies. While the article was short on analysis, my interpretation is that lack of an ultra-reliable last ditch light source contributed to the fatality. A synopsis of the accident is as follows.

o One of a party of four is injured deep within Canada's deepest cave. Injuries preclude self rescue.
o Cave temperature is in the 30's F and the cave is wet.
o Two of party exit cave with plan that one make the 9-hour (one way) hike to summon help while the other returns to the victim with sleeping bags which are located at the cave entrance.
o An extraordinary series of light failures leaves the exiting party with only one operable light source between them.
o The remaining light source (type not specified) uses "AA" cells. A realistic assessment of the projected runtime attainable from the number of "AA" cells on hand determines that the victim cannot be reached.
o Both of exiting party hike out to summon help.
o Despite a large and very well-coordinated rescue effort, the victim is reached too late. Presumably the victim succumbed to hypothermia (my presumption, not specified by the account).

Reflecting on this tragic accident, I developed my criteria for a "last ditch" light source:
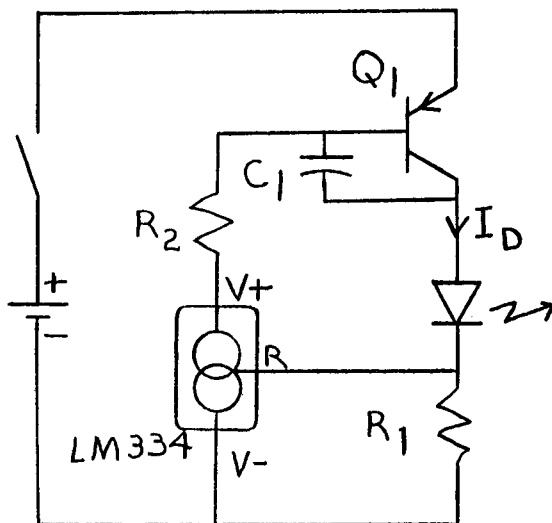
o As reliable as possible
o Provides a level of illumination sufficient that I would willingly solo exit or solo re-enter (i.e., traverse passage that I had previously seen with better illumination) 99% of the caves within my personal experience.
o After 10 years storage under the most abusive creditable conditions will provide a minimum of 12 hours of the above-defined level of illumination at temperatures as low as 32ºF(0C).
o Is sufficiently light and compact that it will never be left behind to conserve weight or volume carried.

The above is a tall order but I believe that I have achieved it. Only longterm reliability is an unknown; look for a follow-up article 10 years from now.

After considerable experimentation I arrived at 50 mA of LED current to meet my illumination level criterion. This current provides roughly the same light as a 1/8" flame on a carbide caplamp. To meet the weight/volume/shelf-life criteria I surveyed the various lithium-cell technologies. Note that lithium cell is by no means a generic term. There are over 10 lithium cell chemistries available commercially, each with their own characteristics which in some cases differ radically. I selected the lithium poly-monocarbonfluoride cell chemistry as it has been mass produced by Panasonic since 1976 and long-term testing since then has indicated excellent capacity retention characteristics. A capacity retention of 95% is typical after 10 years storage @ 68ºF (20C). 90% capacity retention is typical after 1 year storage @ 140ºF (60C). In contrast, an Eveready Alkaline Energizer(tm)
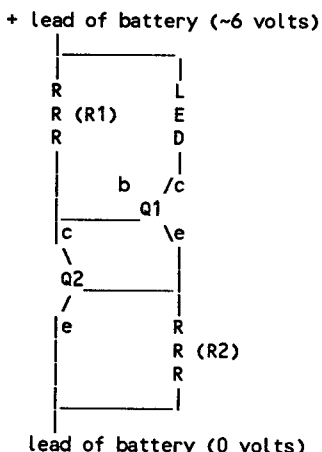
AMBER LED NOTES

Mel Park   NSS 25729

[edited from an article on cavers' electronic mail list; reprinted with author's permission.]

Given the apparent constraints of a steep current-voltage curve (i.e. little resistance) in the HP amber LEDs, powering them with current-regulated supplies seems the only way to go. I like to use constant-current sources using active components to light LEDs, paricularly for battery-powered applications. Three simple circuits, one using a single bipolar transistor, one using a transistor and a zener diode, and one (my favorite) using two transistors are given in my paper "Constant current source for iontophoresis" Journal of Neuroscience Methods 29: 85-89, 1989.

My circuits would probably not work with just two batteries. If the voltage drop across the LED is 2.6 volts, and that across the regulating transistor about 0.7 volts, then we have just run out of complience with just two 1.5 volt cells. A current-limiting resistor, then, seems sensible and we just have to put up with the light getting dim as the batteries run down.

Here is my ascii-graphics attempt at drawing my favorite circuit for powering LEDs. It uses two NPN transistors, Q1 and Q2, wired so that Q2 is providing feedback to Q1, keeping it biased to provide a constant current throught the LED(s). The current through the LED(s) is I=0.6/R2. If the nominal operating current for the LEDs is 20ma then R2 should be 30 ohms. Pick 33 ohms, a standard value. All R1 has to do is pass enough current so that Q1 can operate. That is, at least the LED current (0.02 amps) divided by the gain of transistor Q1, say 100. If we are powering this thing with 6 volts, then R1 should be no more than 6/(0.02/100) = 30000 ohms. Pick 10K to be totally conservative. The transistors can be about any small NPN types, such as 2N3904 or 2N2222. The former are rated at 100mA and have gains of 100 to 300. Look for something like that. With 4 alkaline cells, the load can be two LEDs in series and the circuit should function with constant brightness way down the discharge curve-- I think until the battery-pack voltage drops to below 4.7 volts. You could gang the LEDs in series-parallel configurations so that a single circuit could power 4 or 6 LEDs. The danger here is that if a single LED failed, you could smoke the rest.

```
+ lead of battery (~6 volts)
|_____
|        |
|        |
R        L
R (R1)   E
R        D
|        |
|   b  /c
|_____Q1
|c       \e
 \        |
 Q2_____|
 /        |
|e        R
|         R (R2)
|         R
|_____|
|
lead of battery (0 volts)
```

I breadboarded the circuit using some cheep red LEDs, and observed its performance in the 20mA range. As I thought, the threshold for operation of the circuit is 0.7 V. That is, when the voltage at the collector of Q1

is 0.7 V, referenced to the (-) lead of the battery, the LEDs reach their rated brightness. 4.7 V, therefore, is the minimum required to fully light a set of LEDs operating with a total voltage drop of 4.0 V. As the battery discharges below 4.7 V, the current falls off as a function of the resistance of the LEDs. This means that they dim rather than turn off precipitously. At this point, it might be advantageous to short out one of the series LEDs. Depending on battery type and capacity, you should get the full rated current through the remaining LED or parallel-LED combination.

Using this circuit does mean that 0.7 V or more is not going toward the production of light. It still seems that lots of useful matchings of LED and battery types and numbers are possible...

Current change with temperature seems minimal...well within bounds for this application.

I have been thinking about possible designs. The best combinations center around 4-cell battery packs and two of the amber LEDs in series. For Ni-Cads, this gives full (and constant) brightness throughout the entire discharge curve. At slow discharge rates, the knee in a Ni-Cad's discharge curve seems to be 1.15 V. Four times 1.15 V is just below the minimum voltage of 4.7 V required to make the circuit actively regulate. So at this knee voltage, the transistors are functioning as a forward-biased diode--not actively regulating--but we are in a range where battery and LED impedances match, so we still get light. Overvoltages from freshly charged batteries are, of course, no problem. With alkalines, performance is even more interesting. Alks are generally considered dead when they reach 1.2 V on their discharge curve. This, again, is almost at the active-regulating threshold of the circuit. One could continue to operate the LED circuit as if the thing were a tungsten light, running it until it got too dim. However, you could, as I suggested before, build in a switch that shorted out one LED. Voila, 3 cd (if that is truly their output) of useful light and you can do something people have not been able to do before: march way down the alk discharge curve, all the way to roughly 0.7 V per cell, while still getting useful work out. This is analogous to switching to a low-voltage filament on a conventional electric rig, but with the LED device, if you inadvertently make the switch with a fully-charged system you do no damage. A spdt center-off switch would make the most reliable device, I think. Mud, moisture, and physical shock do take a heavy toll in a cave but I know some people who do hard caving with a miniature toggle switch on their helmet. Actually, I know just one like that...

Output can be increased by making parallel-series ladders. I recommend some testing first: Manufacturing variability usually means that you cannot parallel semiconductor current sources or current sinks. The usual solution is to add a small-valued resistor in series with each parallel arm. I don't know, however, what value I would pick. Based on the numbers John Halleck supplied, the slope-resistance (dV/dI) of the LEDs is 10 ohms. I would start with resistors around that value, but also try to match parts and do some I/V plots of my own if I were trying to make a really bright custom rig.

I predict that HP or some other manufacturer will make hybrid circuits that combine this LED technology and current-regulating circuitry in standard screw-base and bayonet housings. These would replace tungsten miniature lamps in many applications, just as high-intensity fluorescents are replacing incandescents in households that want to afford the initial outlay.
--

A CHEAP AND PORTABLE HOMEMADE ULTRAVIOLET LAMP

by Phil Okunewick <okunewck@cs.psu.edu>

[From cavers' electronic-mail list, 2 Jan 1992. Reprinted with author's permission.]

I've had a wonderful time studying fluorescent cave minerals; most travertine rock will light up under UV. An ultraviolet light source that I can carry underground has been vital.

Construction is almost trivial: The first thing you need is a fluorescent flashlight. These come in all shapes and sizes, just loaded with features that won't do you any good. Try to find one that's fairly robust and has a switch that's easy to operate. A fluorescent/ incandescent combination lamp is very handy (move around using the incandescent bulb), but a flashing amber light feature is useless. Also look for a tube cover that's easy to remove underground; most "clear" covers absorb UV light.

Blacklight fluorescent tubes are available in almost all sizes, made by Phillips, GE, Sylvania, and probably others. Go to your favorite commercial lighting distributor (the type that supplies electrical equipment to contractors) and order your tube size with a "/BLB" suffix. This is a Longwave UV tube with a UV filter coating on it - not great, but more than adequate for general use. A small one should cost under $10; I paid about $8 for a F4T5/BLB.

As the fluorescent flashlights are wide-area floodlights, you want a reflector to keep the light out of peoples' eyes. You also want a reflector that won't fluoresce and emit visible light. I cut one out of a 2-litre soda bottle, folded it to fit around the back and sides of bulb, and covered it with metallic silver contact paper ($1/yard at the hardware store). Use whatever is handy to fasten it to the old reflector behind the bulb; I used rolled-up pieces of Scotch tape. Shiny metallic duct-tape may make a good reflector too. Try aluminum foil if you can't find anything else.

Clear plastic has odd behaviors under UV. Some kinds will block UV completely; others will pass UV, yet fluoresce as well. Neither case is desirable; leave the cover on to protect the tube but remove it to view rocks.

The other modification I made to my light was installing momentary switches to operate the bulbs. These are really handy for moving around and viewing phosphorescence - instead of fumbling with an inconvenient 5-position switch, just release the momentary button to turn the UV lamp off. (If you get a lamp with a nice switch, momentary switches aren't necessary.)

If you want a better light, use an unfiltered tube behind UV-transparent filter glass to block the visible light. The longwave tube (/BL suffix) is available in all sizes too, but I haven't found a shortwave tube (G prefix, "Germicidal") shorter than 10 inches (G8T5). I also haven't yet found a local supplier for UV filter glass; I hope to remedy that soon. Both longwave and shortwave lamps are needed for serious study: Shortwave UV has higher energy (more stuff will fluoresce), but the effect produced by longwave UV is significant too.

I don't recommend filtered incandescent blacklight. These are standard 75-watt bulbs with a UV filter painted on; they put out about 74 watts of heat and 1 watt of UV.

WARNING: SHIELD THE UV LAMP FROM PEOPLE'S EYES, as these things will "sunburn" your retinas-- the irises don't react to the UV, and let in far too much light. You can find plastic safety goggles or plastic perscription glasses with UV-opaque lenses. I've been told that glass prescription glasses can block UV as well. To test, illuminate a strongly fluorescent white cloth with the lamp several feet away. Put the lens almost against the cloth and see if it casts a total shadow. I have one pair of safety goggles that completely block UV, but another pair don't block UV at all.

Fluorescense is best viewed with your eyes accustomed to total darkness. Rest your eyes in the dark for a minute or two before lighting things. When viewing phosphorescense (afterglow), keep your eyes closed and open them a fraction of a second after you turn the lamp off. Tapping the specimen to make a small noise will help your eyes keep track of it while they're closed. For moving around, you might even cover the incandescent bulb with a piece of red plastic to avoid reducing your night vision, though this will distort your color perception.

An interesting side effect is UV phosphorescense in the lamp itself. I have a cloth that glows incredibly brightly under UV; when the lamp is turned off it still glows slightly under the lamp. It's something that should be kept in mind when viewing faintly phosphorescent specimens - move the lamp away as you turn it off.

A good book on UV lamp supplies is The Collector's Book of Fluorescent Minerals by Manuel Robbins, published by Van Nostrand Reinhold Co, c1983, still in print when I checked about 6 months ago. Price is about $65 (yow!); fortunately the local library has it. This doesn't really cover cave minerals; it's an overview of all fluorescent minerals. The chapter on UV lamps is very useful. (To my knowledge there is no good book on fluorescent cave minerals. Yet.)

The ultraviolet light has opened a whole new aspect of caving to me. Not only are the views spectacular; there are a lot of things that can be learned about minerals from their fluorescent behavior, and still other mysteries that can be uncovered.
--

Ed note: Radio Shack 61-2734 is a satisfactory fluorescent flashlight for caving. It requires two C-cells, and has an incandescent bulb in one end. Doug Strait has researched battery-powered fluorescent lights extensively and has found that most commerically-available dc fluorescent fixtures are not only inefficient, but cause their tubes to deteriorate rapidly (~100 hours). The waveform supplied to the tube results in permanent darkening at one end; the tube should last longer if rotated end-for-end after every few hours of use.

UV light and fluorescent cave-mineral references:

Photos of luminescent cave minerals wanted. Speleonics 12 p13.

Resources: Ultraviolet lamps for mineralogy. Speleonics 12 p14.
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+----------------------------------------------------------+
|    "Hams across the water, hams across the sky."         |
|                  -- P. McCartney's DXpedition song       |
+----------------------------------------------------------+
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RESOURCES AND INTERESTING REFERENCES

[Products mentioned here are not paid ads.]

IKELITE UNDERWATER SYSTEMS

50 West 33rrd Street
P.O. Box 88100
Indianapolis, Indiana 46208
ph: (317) 923-4523

Ikelite manufactures high-intensity dive lights, underwater housings for cameras and video equipment, and other interesting items, many of which are applicable to caving. Write for catalog. They must be good guys because they read SPELEONICS!

"Listening to Nature's Radio" by Speleonics reader **Michael Hideke** in Science Probe! magazine, July 1992 p87 is a concise introduction to natural VLF phenomena (whistlers, etc) and includes plans for a simple but effective receiver. Underground and cave-radio-related experiments with such receivers are fascinating, and I hope to report on them in a future issue of Speleonics. --FR

WHY NOT TAKE OUT A SUBSCRIPTION?

RADIO BYGONES

Morsum Magnificat
Magazine for Morse Telegraphy


PIEZOELECTRIC SOUND-POWERED TELEPHONE

Frank Reid

Radio Shack's "piezoelectric speaker element" (part number 273-091, $2.49) works as a sound-powered telephone transducer. One transducer at each end of a pair of wires makes a simple telephone system which is compatible with with TA-1/PT military sound-powered phones (see SPELEONICS 17). Speech is fully intelligible despite the device's unusual frequency response. The device is manufactured by MuRata Corporation of Japan.

I subjected one device to about 100 volts from the hand-powered generator of an army field phone. It flexed visibly and emitted faint clicks, but appeared undamaged.

Electromagnetic sound-powered transducers in TA-1 telephones are delicate, and replacements are hard to find. The piezoelectric transducer may be a viable substitute. Experiments continue; range and humidity-tolerance are undetermined.

Actual size:
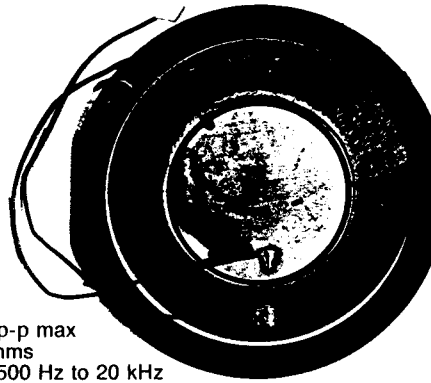
Input Voltage: 30V p-p max
Impedance: 1200 ohms
Frequency Range: 500 Hz to 20 kHz
Lowest Resonant Frequency: 900 Hz
Capacitance: 140nF ±30%
Operating Temperature: −20°C to +70°C

Input Volt: Sine Wave 1Vrms
Measuring Distance: 10cm
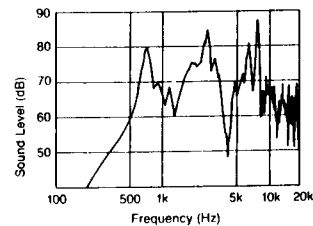
CHARACTERISTICS OF BULBS USED IN MINI-MAGLITE(tm) FLASHLIGHTS

Douglas Strait NSS 9707

The following data were obtained from the Maglite company concerning the bulbs used in AA and AAA cell Mini-Maglites flashlights.

Number & type cells	Design voltage	Design current	Design Life (hr)	Design MSCP($\pm$10%)	MSCP/ watt
2 AA	2.30V	.300A	20	.37	.54
2 AAA	2.30V	.125A	20	.15	.52
1 AAA	1.25V	.220A	20	.06	.22

The 2-AA cell model flashlight seems to be the most popular among cavers. For many it is their first redundant light, i.e., the light they would use upon failure of their primary light. With fresh (alkaline) cells and moderate cave temperatures (>50°F [10C]) about 5 hours of runtime is obtainable. Assuming that one is diligent in maintaining fresh cells in his backup light, this is adequate for most situations. Those who can conceive of needing more runtime from their 2-AA Mini-Maglite, but do not wish to carry spare batteries, should consider replacing the spare bulb which is stored in the base of the flashlight with a bulb designed for the 2-AAA cell Mini-Maglite. This bulb will provide about 12 hours of runtime in a 2-AA Mini-Maglite vs the 5 hours of the standard bulb. The light output is, of course, reduced as can be seen from the table. The output of the 2-AAA bulb is barely adequate to cave by but is a vast improvement over 7 hours of darkness if one is ever in a situation requiring 12 hours of runtime from their Mini-Maglite.

RADIO FREQUENCIES OF INTEREST TO CAVERS (USA)

CB ch.2	(26.975 MHz)	Cavers' channel, NSS conventions
147.48	Cavers' simplex, NSS conventions	
151.625	TRA (Old Timers' Reunion).	
155.16	Nat'l Cave Rescue Commisssion (Eastern Region)	

SELECTED NATIONAL PARK FREQUENCIES

Ref: Popular Communications magazine, February 1987.

Buffalo River, AR	164.25	164.475	164.75
Carlsbad Caverns, NM	164.425	164.9875	
Cumberland Gap KY/TN/VA	166.3	166.7875	
Grand Canyon, AZ	171.75	172.425	172.45
Great Smokey Mts. NC/TN	166.35	167.15	408.725
Mammoth Cave, KY	169.55	170.1 (rpt in, no PL)	
Jewel Cave, SD	170.05		
Joshua Tree, CA	171.675	172.675	
Lehman Caverns, NV	163.15		
Sequoia, CA	164.25	164.75	172.45
	166.875	171.75	172.45
	172.5	173.7875	417.925
Wind Cave, SD	170.05		
Yosemite, CA	171.65	171.775	171.8
	172.025	172.65	172.675
	172.775		

Author's address (see article p.5) -->

FLASHLIGHT SURGERY

Duke McMullan [N5GAX, NSS 13429]

[edited from original posting on cavers' electronic mailing list, 2 June 1992. To join, send internet e-mail to cavers-request@m2c.org.]

Anmar Mirza's description [SPELEONICS 17] of how to disassemble the switch assembly of a Maglite(tm) motivated me to do similar sacrificial disassembly of a Brinkmann clone of the three-D-cell Maglite.

The switch of my Brinkmann Pro-Max(tm) had developed a most annoying habit of jamming in the down position, whether on or off. Several attempts to remove the switch assembly had failed, but Anmar's article convinced me that it was worthwhile to try again. No luck: The Pro-Max has no screw under the rubber switch-boot like that of the the Maglite.

After unscrewing the head of the flashlight, a retaining C-ring must be removed to lift out the lamp holder. Separated by a compression washer, it sits atop a plastic barrier through which protrudes a single brass strip which contacts the base of the lamp. (A reason the Brinkmann line is cheaper than Maglite: all brass, no silver.)

The switch assembly is below the plastic barrier, and no mechanism was evident for releasing it: I rammed it out with a broomhandle. Parts flew in all directions, and I never found them all. However, the reversible method for removing the switch was now evident.

The switch assembly is a plastic cylinder slightly larger than a D-cell, which fits snugly into the flashlight's barrel between the battery compartment and the lamp assembly. Opposite the switch-hole in the barrel is a small, shallow hole into which fits a spring-loaded peg on the switch assembly. It's a "living-spring" sort of arrangement, the whole simply molded as part of the cylinder. Running from the lamp end of the switch assembly is a shallow 1/8-inch-wide groove. A thin piece of shim stock (I used some .022" steel that was lying about) about 2.5 inches long was pushed down the groove (in a NEW flashlight), and allowed the switch assembly to be removed without damage. Note that with the switch cylinder in place, only the end of the groove is visible as a narrow and thin slot at the top end of the cylinder, at the periphery, on the side opposite the switch.

Once released by the shim, the cylinder will slide (with some persuasion-- use a broomhandle GENTLY) toward the front of the barrel. Reinsertion is a reversal of removal, depressing the peg and the switch to get the cylinder to fit into the barrel.

The switch cylinder from the old Pro-Max, regrettably, is history, and I guess I'll have to write the manufacturer to see if they will supply replacement switch assemblies at reasonable price. Separate replacement button boots would be nice, too.

If they decline, I believe I can replace the original switch with a push-on/push-off panel-mount switch. It won't be waterproof, nor as durable as the original. It shouldn't matter, since I don't use it in caves any ay.

These large flashlights (as opposed to the one using AA and AAA cells) are known in some circles as B.I. (Blunt Instrument) flashlights.

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