Operation of the Bisun B21caving light

The rotary switch in the headset containing a B21 is used to control both wide and spot beams, in a similar (though slightly more complicated) way to operation with conventional incandescent bulbs.

The control circuits for the two beams are entirely independent, and each is connected to a different contact on the switch. To understand the overall lamp operation, it is best to consider only a single beam and its half of the switch. The other beam works in exactly the same way, but is controlled by the other half of the switch.

Each time the switch contact for a beam closes or opens, the beam will change state - either altering its power level, or switching off. The key thing to remember is that whenever the switch for a beam is closed, the beam will be at high power, and whenever the switch is open, the beam will be at medium or low power, or off. When this document refers to a *switch* being on (or off), it should be understood that means the same as the switch being closed (or open), and it does not refer to the state of the beam that switch is controlling.

Simple Mode

In simple mode, a beam is on at high power whenever its switch is closed. When its switch is open, a beam is either at medium power or off, depending on the recent history of operation. If the switch is opened twice within ~3 seconds, the beam will be off, otherwise the beam will be on at medium power.

Put another way, what this means is that if the switch is alternately closed and opened quickly, the lamp will go through the simple cycle:
off->high->medium->high->off
If the switch is operated occasionally, and is not opened **twice** within 3 seconds, the beam will switch between high and medium power with each closing or opening of the switch. This means that occasional changes to the power level underground will not result in the beam turning off, but the beam is easy to turn off when desired.

Advanced mode

Advanced mode is similar to simple mode, but with an extra low-power setting available.
If the switch is operated quickly, the basic advanced-mode cycle is:
off->high->low->high->medium->high->off
If the switch is operated occasionally, and is not opened **three** times within 3 seconds, the beam will go through the indefinite cycle of high->low->high->medium, etc.
If a beam in advanced mode is on, and the switch hasn't been operated in the last 3 seconds, 3 switch openings in quick succession will turn the beam off.

The high power setting corresponds to a current consumption of ~360mA, with a light output of upwards of 30 lumens.
Medium power is ~1/3 of the high power setting in terms of current consumption and light output
Low power is ~1/4 of the medium power setting in terms of current and light output.

While familiarising yourself with the lamp operation, it should be noted that since the LEDs are more than bright enough to leave temporary dark spots in your vision, it is best to practice using the light while it is mounted on a helmet, or otherwise pointed away from the eyes, and in a space sufficiently dark to enable the various power levels to be investigated, or with a suitable relatively unlit surface to use as a target for the unit.

Practicing *blipping* the switch - (quickly turning it from off to on and then back to off via a small movement of thumb and forefinger) is recommended. In a headset mounted on a helmet, this

is probably easiest if the switch is in the off position such that turning the switch clockwise (top forwards) will operate the contact for the beam in question. In real-life usage, it is most common for the spot beam to be turned on and off more often than the wide beam - many people leave the wide beam on medium or low throughout a trip, and turn the spot beam on briefly when desired. For such operation, it is suggested that the switch is habitually left in the 'off' position such that a brief turn forwards (clockwise) will operate the spot beam, since a forwards blipping of the spot beam to turn it on or off is easy, and it can be convenient to leave the switch in one standard position to make it easier to know which way to turn it. Particularly if using advanced mode, just turning the switch round and round is unlikely to select any particular desired combination of lighting levels.
To examine the state of the wide-angle beam, it is best to turn the spot beam off, as an operating spot beam may make comparison of the various wide-angle power levels difficult.
To turn off a beam in advanced mode, as an alternative to three successive blips, it is worth experimenting with a *through* manouvre - a half-turn from one off position to the other off position through the on position for the beam in question. Three through manouvres in short succession (alternating in direction) will turn the beam off.

It should be pointed out that headsets can vary greatly in the amount of tactile feedback they provide to the user via the switch-control knob. Some headsets use a round knob which gives no indication of the switch position, and in some headsets, the friction on the switch knob largely masks any mechanical feedback caused when contact is made or broken by the rotating switch arm, though a few minutes of cleaning and greasing of the shaft can greatly ease such friction in most cases.

Jumper-in and jumper-out operation.

The unit is supplied with a 'jumper' fitted - this is the small block sticking out of the side of the circuitry block, which can be removed by pulling on it, leaving the two pins which it slides on exposed. If the jumper is removed, it is recommended that it is kept safe for later use (sellotaping it inside the heaset is possibly the best option).
With the jumper present, both beams on a B21 operate in simple mode (two power levels), and with the jumper missing, both beams run in advanced mode (three power levels). The B21 only checks the state of the jumper on battery connection, so changing the operation of the light requires a brief battery disconnection and reconnection

On a B21, the power *levels* for each beam are also persistent - battery disconnection while a unit is running will cause a temporary loss of light, but on reconnection the beams will power up at the brightnesses they were previously running at, giving a unit which operates much as a regular bulb would do, even with an intermittent power supply (like a Headlite pack with old/worn battery connections).

The actual power settings (low, medium, or high) being used by the beams are not stored until they have been unchanged for a few seconds, so a battery disconnection *immediately* after changing power levels may result in powering up at previously stored power levels. This should not be a problem in practice, and is only likely to happen in the case of particularly bad battery connections, which should probably be attended to for other reasons.

General Usage
In practice, it is expected that advanced mode is most likely to be used when battery economy is of greatest importance, such as when expedition caving, or in a low-battery situation, though it can also be useful to have a low power mode available when just waiting around underground.
If sitting around waiting with other cavers, it is considerate to avoid running the wide-angle beam at full power - at any given power level, the spot beam will be less dazzling for other cavers as long as the beam is directed below the level of their face

Some frugal cavers with good vision may find the low setting of the wide beam adequate for general use use when moving steadily in known cave passage, with occasional use of spot beam when distance illumination is required. In such a situation, very long battery life (roughly 7x24h of constant use) might be obtained from a 4.5V MN1203 battery.
It may be noticed that when low power is selected, the LED will flicker a little for the first few seconds, and then stabilise. This is an entirely normal part of the circuit operation.

If/when the battery becomes depleted to the point where it cannot sustain the beam at the desired power level, the beam will simply be run at whatever level the battery can sustain, and slowly decline in brightness. A good indication of battery delpetion is if switching between medium and high power settings produces little of no change in brightness.

Battery life

The approximate nominal capacities of various batteries are given below

NiMH AA	1800-2400mAh
Alkaline AA	~2700mAh
Headlite (NiCd, high capacity)	3000mAh
NiMH 7/5 AF cells	3500mAh
NiMH '18670' cells	4500mAh
4.5V alkaline 'flat pack' (Duracell MN1203 or equivalent)	5500-6100mAh

One beam at high power with the other beam at medium gives roughly 2 hours per amp-hour
One beam at high power gives roughly 3 hours per Amp-hour
One beam at medium power gives roughly 8 hours per Amp-hour
One beam at low power gives roughly 30 hours per Amp-hour

It might be expected that an MN1203 or equivalent battery would deliver approximately 15 hours of high power, 45 hours of medium power, or 170 hours of low power.
In real-life situations, things are a little more complicated. The voltage of alkaline batteries drops gradually during discharge, from an initial 1.5V/cell to about 1.0V/cell at the end of their life, whereas a NiCd or NiMH cell tends to give a broadly constant 1.2V/cell until nearly depleted.
Additionally, at high current drains, an alkaline battery will not supply anything like the nominal amp/hour capacity (for example, alkaline AA cells of ~2700mAh nominal capacity may only supply ~800mAh before exhaustion with a 1A drain, or 1600mAh with a 500mAh drain), and so the battery life at high power may be much less than expected.
A part-depleted 4.5V alkaline battery may just fail to supply enough voltage to fully power a beam at high power, but may still be capable of supplying a medium-power beam for many more hours. In contrast, with a 3xNiCd or 3xNiMH battery, something closer to the simplistically calculated life (~2.5-3 hours of high power per nominal battery amp-hour) should be obtainable.
Once a rechargeable battery is exhausted to the point where noticeable dimming occurs on high power, it is generally a relatively short further time before the battery is incapable of supporting even a medium power beam.
Low temperature *can* reduce the output of alkaline cells, though above freezing point, this effect is often not very severe.

Experimental example (one beam operating):
Using 3x2000mAh freshly charged NiMH cells, high power was sustained for 4h38m, then the lamp was switched to medium power and ran for a further 0h54m, Then, with the lamp still running on the medium setting, the power had declined to half the medium-power level (twice the low-power level) after a futher hour.
In this case, if the beam had been started on medium power, it would probably have lasted for 14-15 hours before starting to decline. Assuming the cells actually did have 2000mAh capacity, the output dropped below the usual high power level at about 80% of capacity, and then after switching to medium power, that lasted for anothe ~5% of the nominal life before medium could no longer be sustained.

It can be seen that even with rechargeable cells, which tend to have a steep drop-off of voltage when nearing exhaustion, there was a fairly gentle decline of output as the batteries emptied.
Real-life example:
With a prototype lamp, a caver executed one 8-hour trip, and two subsequent three-day underground camping trips, (generally using one beam on medium power) on a single Duracell MN1203. Though the eventual output had declined below the regular medium power level, the user was still quite satisfied with the light output after his seven days of use - a spot beam running at well under medium power is still more than adequate for safe caving.

In fact, though not ideal, a spot beam on low power gives adequate light for moving around in emergency situations, with a quite usable short-range spot beam, and consumes less electricity than most old single-5mm-LED lights. *If some serious situation did arise which made an unexpected stay underground likely, and spare batteries were not available, it is worth the user making sure their lamp is in advanced mode (removing the jumper from the circuitry) and running the B21 on low power where possible, which should give hours of usable light even from a nearly-dead battery.*
The power controller has a very low power consumption when a beam is off, and as a result, disconnection of the battery when the lamp is not in use is not strictly necessary as long as the user is confident that the switch will not accidentally get turned on. However, for long periods of non-use, it is probably advisable to disconnect the battery.

Warning - The supply for a B21 should be limited to no more than ~5 Volts, which realistically usually means a 3-cell alkaline, NiCd or NiMH battery, or a 3.7V Lithium pack. Use of 4x NiMH cells would be possible, but would give no extra life compared to 3 cells, and would simply waste heat in the circuitry, though 4xNiMH/NiCd AA cells in the Headlite battery boxes sold to hold 4.5V alkaline packs would be fine, especially since the built-in diode in such boxes drops some of the excess voltage.
Use of an FX5 battery would risk serious damage and should not be considered.
The control circuits are protected against reverse voltages that can occur due to incorrect installation into a headset, or from misconnection of a battery.

Care of your unit.
Whilst the circuitry is potted in resin, has so far proved immune to water problems, and is likely to temporarily fail safe even if water did somehow penetrate the resin, it is still advised to avoid getting water in the headset, primarily because of the potential effect on the reflector silvering.
If the headset does get water inside, it should be opened and allowed to dry thoroughly as soon as possible after exit. Mud should be gently rinsed off, ideally not with hard water. Care should be taken not to touch or otherwise damage the reflector surface, as this may allow water to penetrate the thin lacquer coating and corrode the metal reflective layer underneath, impairing spot-beam performance. If the unit is to be fitted to a headset known to have leaked in the past, it is best to address the waterproofing issues of the headset before fitting the unit.
That said, one test user has operated a prototype B17 (essentially the same design as a B21) in a headset left almost permanently damp inside for a year of weekly digging and monthly sport-caving trips, with no apparent problems

Finally, despite the effort put into making the B21 as reliable as possible, with independent control circuits for each beam, and built-in redundancy within each control circuit, it is still recommended to carry backup lights when caving, as one would with any other light source.
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