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OPERATIONAL NOTE

ARE YOU STILL USING 6-VOLT BATTERIES FOR YOUR INSECT TRAPS?

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ABSTRACT. The most prevalent insect sampling and surveillance problem is powering insect traps in the field. Most modern light traps use 6-V power supplies such as the Centers for Disease Control and Prevention (CDC) suction trap. Buck converter modules efficiently reduce 12-V direct current power to 6-V, which permits the use of higher voltage batteries with lower voltage traps, resulting in longer operational duration and reduced labor requirements associated with replacing and recharging batteries in the field. We evaluated several battery configurations of 6- and 12-V lead-acid batteries in various sizes (10–20 ampere-hours) and addressed, in the circuit design, common problems that occur when using the buck converter (such as crossing polarity and excessive battery depletion). The efficacy of each configuration was assessed by measuring the voltage and suction while powering a 6-V CDC light trap. The buck converter permitted the use of cheaper and more commonly available 12-V batteries to run the CDC light traps and resulted in longer effective operation time as measured by air speed.

KEY WORDS Battery power conversion, mosquito surveillance, trapping, trap power longevity

Methods used to survey mosquito vectors in the field can vary depending upon the species of interest, survey location, and the availability of a reliable power source (Cohnstaedt et al. 2008). One of the more common surveying methods involves the use of devices containing lights and fans to attract and then trap flying insects in a container. Generally referred to as "light traps" and used throughout the world, the forerunner to current light trap designs was initially developed in 1927 (Reinert 1989). The New Jersey light trap was originally designed to operate with household (mains power) current powering an incandescent bulb and fan. Due to reliance on 110-V alternating current power sources and heavy, bulky design, the New Jersey light trap was not easy to use for field surveillance. Later modifications incorporated a 12-V power source and fluorescent tubes for light (Reinert 1989). Incorporating a 12-V power source allowed for flexibility in trap placement for field surveillance. Surveying methods using 12-V power was the standard for many years; however, manufacturers began developing traps using cheaper, smaller, and more energy-efficient 6-V motors for the fans (Nelson and Chamberlain 1955). Researchers then attempted alternative power schemes that focused on convenience and portability: D-cell disposable battery packs, AA battery packs, inline resistors, solar panels as well as household current adapters (Sudia and Chamberlain 1962, Smith and Downs 1969, Johnston et al. 1973). As 6-V fan motors became the standard, 12-V power was stepped down using inline ceramic resistors, though these produced enough heat to cause harm to the operator. Eventually, traps moved away from incandescent bulbs and fluorescent tubes to 6-V light-emitting diode (LED) arrays (Burkett et al. 1998, Cohnstaedt et al. 2008).

Despite the use of 6-V systems, light traps for mosquito surveillance are still hampered by power source requirements, and most 6-V, 10 ampere-hour (Ah) batteries run for a single trap-night before requiring recharging. Additionally, 6-V batteries with the necessary amperage-hours for long-term surveillance (>20 Ah) are more expensive and difficult to find compared with 12-V batteries found in all motorized vehicles. Furthermore, there are no 100-Ah batteries (car battery size) in 6 V. An inexpensive and easy-to-implement power conversion process that utilizes 12-V batteries for 6-V systems will be cheaper to use and easier to maintain. The conversion system requirements are to be effortlessly fabricated and incorporated as well as easy to use and reasonably priced with readily available components. Switch-mode step-down power converters commonly referred to as "buck converters" provide an efficient means of stepping-down direct current (DC) voltage with a relatively small footprint. We evaluated the performance of two 6-V Centers for Disease Control and Prevention (CDC) Miniature Light Traps (Bio-Quip, Rancho Dominguez, CA) using various amperage-hour batteries of both 6 and 12 V using a LM2596 DC-DC (Atnsinc; Amazon, Seatlle, WA) buck converter module with the 12-V batteries.

To test the efficiency of various power systems, 6-V CDC Miniature Light Traps ($n = 2$) with similar brownout voltage and current draw were attached to power sources. These sources were: (1) one 12-V 20-Ah battery with a buck converter, (2) one 12-V 10-Ah battery with a buck converter, (3) one 6-V 20-Ah battery, (4) one 6-V 10-Ah battery, (5) two 6-V 10-

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Table 1. Fan wind speed velocity averages (mph) measured below the trap correlate to the trap suction and higher voltage results in faster fan speeds and better suction. As the batteries lose potential (V) with time, the fan speed decreases.

	12 V		6 V		Parallel 6 V	Series 6 V
Time (h)	20 Ah	10 Ah	20 Ah	10 Ah	10 Ah	10 Ah
0	22.2	21.8	19.5	21.3	21.8	16.7
8	19.5	19.0	17.6	17.1	20.1	16.7
12	19.5	19.5	16.5	15.0	20.1	16.1
24	19.3	0.0	8.4	0.0	15.9	0.0

Ah batteries in parallel, and (6) two 6-V 10-Ah batteries in series with a buck converter. The study design allowed for comparisons of 6- and 12-V batteries with comparable amperage-hours. Buck converters were not used in 6-V power systems. A Digilent Analog Discovery Board 2 (Digilent, Pullman, WA) was used for data acquisition (voltage) and 2 CDC traps were run simultaneously using channel 1 and channel 2 of the board. Data were collected directly from the connection points as Trap Voltage. Depending on the test, connection points were also connected to the output of the LM2596 buck converter (12 V) or directly to the battery (6 V). The Discovery Board fed data to a tablet computer (Surface Go 2; Microsoft, Redmond, WA) that powered the board and ran the WaveForms application (WaveForms; Digilent). The analog discovery board read the data from channel 1 and channel 2 with Range set to 2-V/div. Once a test was completed, the relevant trap voltage data were collected from the "data" graphic and transferred into an Excel file (Microsoft, Redmond, WA). On all voltage tests, wind speed checks were performed using a Maximum Model BTC994 handheld anemometer (Maximum Weather Instruments, New Bedford, MA). The measurements were taken at initiation of the system (time 0), 8, 12, and when applicable at 24 and 48 h. To measure the wind speed, anemometer cups were placed as close to the trap fan as possible without touching the fan blades or circular plastic enclosure. The push wind speed data were measured in knots and later converted to miles per hour.

The LM2596 DC-DC buck converter modules were selected due to availability and ease of use. These modules include an adjustable output voltage set by a screw on the module that can output 1.5 A reliably (3 A maximum) and handle voltages ranging from 3 V to 40 V without impacting the output voltage. Twelve-volt inputs to the buck converter (Fig. 1a) were measured on the output leads using the digital multimeter to monitor the output voltage going to the trap. The potentiometer on the converter module was adjusted until a steady 6-V output was achieved. Single 12-V 20-Ah and 12-V 10-Ah batteries were connected to the input of the buck converter, connected to the trap terminals and the Discovery Board pins. Data collection was set up before connection and started recording once fully connected. A protection circuit in parallel with the connection was inserted before testing, providing a path for the current should the leads from the battery be reversed (crossed wires when connecting to the battery). This protection circuit prevents damage to the converter and illuminates the LED warning the operator of an incorrect connection. Finally, the buck converter was deployed in the field, powering a CDC miniature light trap solely on a 12-V 100-Ah deep cycle car battery and operated continuously for 21 days before battery replacement. During operation, the converter was exposed to environmental conditions including rain, wind, and sunlight.

A slight difference in starting voltages was caused by battery recharging inaccuracies, but this did not impact the test starting point. The system ran until a threshold of 5.3 V was observed on the waveform application (Fig. 1b) and the testing ended. After recharging, the power sources were evaluated a 2nd time with the other trap and the results, from each, were entered in Excel and the mean was calculated resulting in average trap voltage versus time curve (Fig. 1b). The 6-V 20-Ah and 10-Ah batteries were evaluated the same as the 12-V 20-Ah and 10-Ah; however, instead of being connected to a buck converter, the batteries were connected directly to the trap. Without a buck converter to regulate the voltage, the inaccuracies in recharging are more prevalent in the 6-V test starting points. For the 6-V series 10-Ah tests, two 6-V 10-Ah batteries were connected in series to simulate and most closely approximate a 12-V 10-Ah battery. Once connected in series, the test was performed the same as the previous 12-V tests. In the parallel tests, two 6-V 10-Ah batteries were connected in parallel to simulate a 6-V 20-Ah battery and run as described. As seen in Fig. 1b the voltage drop is lengthened when using a 12-V 20-Ah power source system, allowing researchers to run a trap continuously for 24 h. In addition to the benefit of an increase in trapping time, the average wind speed (Table 1) is maintained longer with the 12-V power source using a buck converter. Given the universal availability of 12-V batteries, the buck converter has proven its utility to combine readily available battery options and insect traps that require 6 V. Twelve-volt batteries are available worldwide due to their use in automobiles and motorcycles. Larger batteries have deep charging features that allow for the easier discharge and recharge without damage and can be purchased with 100+ Ah. Most accessories are tuned for 12-V

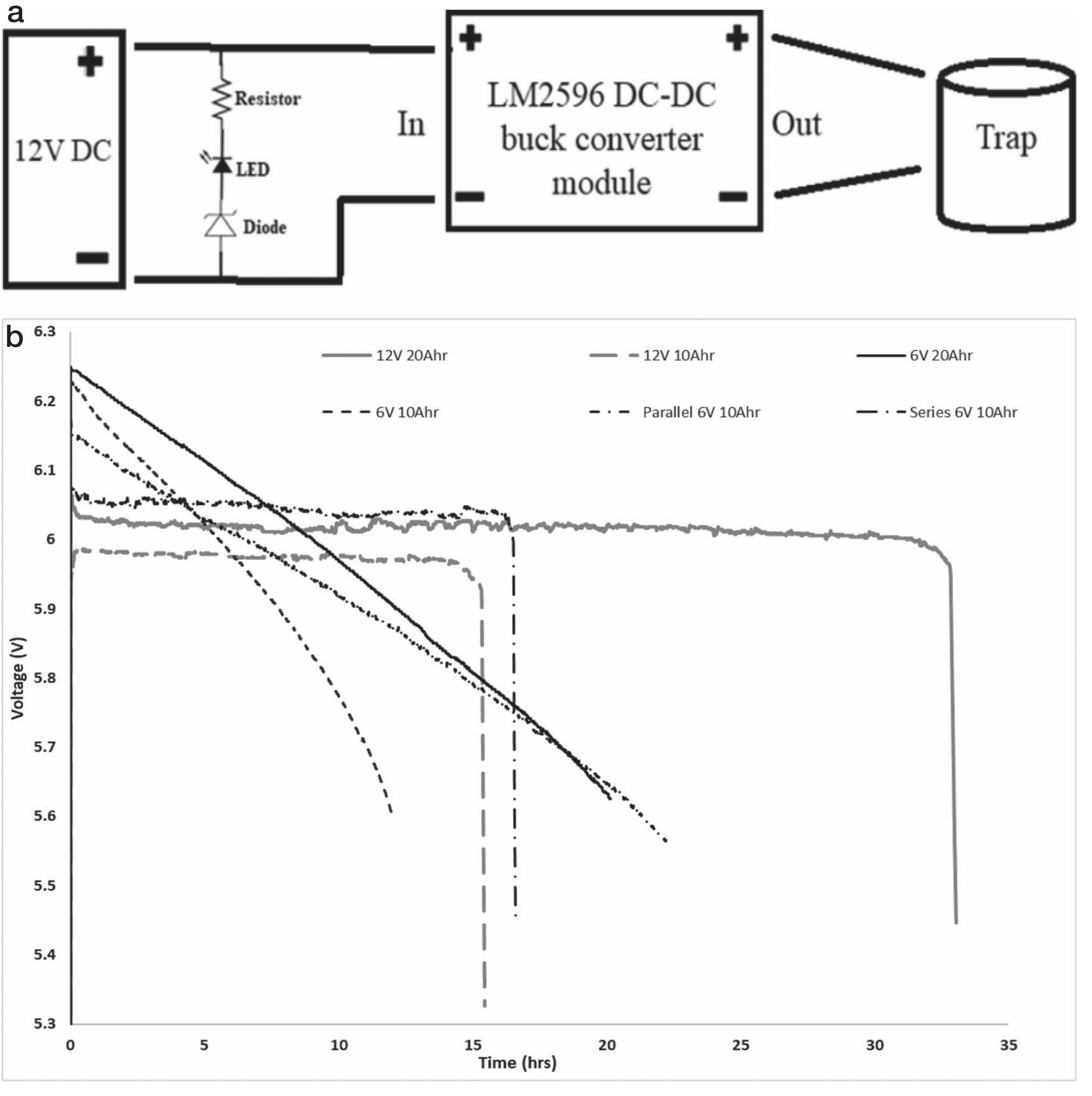

Fig. 1. (a) Wiring diagram of how to install the buck converter module in a trap. The indicator light-emitting diode (LED) and diode prevent damage to the buck converter if the battery leads are crossed during installation. (b) Battery potential (voltage) declines as the batteries are used. This decline results in slowing of the fan and corresponding reduction in suction. Therefore, the longer the voltage stays high, the better the trap maintains suction. The 12-V batteries maintain the required voltage more consistently than the continually declining 6-V batteries.

batteries, such as wall chargers and solar panels. The benefit of long-lasting power from 12-V batteries in the field are immeasurable. Whether traps use 12 V or 6 V, having the option to use both in the field on 12-V batteries efficiently is needed and economically advantageous.

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