# Overview of NIOSH LED Cap Lamps

The NIOSH Office of Mine Safety and Health Research (OMSHR) is conducting mine illumination research to address the visual needs of the aging miner workforce and to improve miner safety by reducing glare and improving a miner's ability to see mine hazards associated with slip/trip/fall accidents and moving machinery accidents. This research enables improvements in mine lighting so that miners can better see hazards; thus, the research will enable a reduction of accidents. The result of this research is an MSHA-approved, light-emitting diode (LED) cap lamp model called the GEN 4. Also developed were similar models—the GEN 5, the GEN 4E, and the GEN 5E—with other features as described below.

**NIOSH-developed LED cap lamp GEN 4 model.**

The company LED Specialists designed and built the printed circuit board (PCB) for all models of the cap lamp according to NIOSH specifications. This company also programmed the PCBs for models GEN4 and GEN 5. OMSHR researchers modified this software for the models GEN 4E and GEN 5E. NIOSH also created a documentation package for each model of cap lamp. The files created by NIOSH and by LED Specialists are in their respective folders of the documentation package, available for download from the NIOSH Mining website at www.cdc.gov/niosh/mining.

**GEN 4 Model**

NIOSH developed the GEN 4 for use in underground coal mines. The GEN 4 uses the battery, battery cable, and headpiece of an existing MSHA-approved cap lamp that is commercially available. Researchers retrofitted this existing cap lamp with new optics, three LEDs, an LED mounting plate, a printed circuit board (PCB) that provides programmable functional control of the cap lamp, and a single integrated circuit (IC) driver with three constant current sources for the LEDs. NIOSH research was the basis for the retrofit of all components and associated software. The GEN 4 model is MSHA-approved for use in underground mines.

**GEN 5 Model**

A second LED cap lamp, model GEN 5, was developed by NIOSH to better suit the visual tasks performed in underground metal/nonmetal mines. The primary difference from the GEN 4 is that a more intense spot beam is available for illuminating objects or mine areas that are 40 feet or greater from the cap lamp. NIOSH achieved this with a change in the LED and optic used for the spot beam as well as modifying the PCB to have dual IC drivers that enable the spot beam to operate at a greater range of current. The GEN 5 model is not MSHA-approved for use in underground mines.

**GEN 4E and GEN 5E Models**

The next cap lamps NIOSH developed—models GEN 4E and GEN 5E—were reduced-power versions of the GEN 4 and GEN 5 with both hardware and software changes. These reduced-power models can operate using a single lithium-ion battery cell. Both the GEN4E and GEN 5E can provide at least 11 hours of operation at the highest cap lamp intensity. The GEN 4E and GEN 5 models are not MSHA-approved for use in underground mines.

# GEN 4 Cap Lamp Overview
# Intended for Coal Mining

1.1. Temperature range:
   1.1.1. Operational ambient temperature is 0° C to 40° C.

1.2. Functional requirements:
   1.2.1. The GEN 4 cap lamp uses three LEDs. The LED drive currents, in milliamps (ma), depend on the external switch and battery condition as listed by Table 1.

**Table 1 - The GEN 4 cap lamp functions**

| Condition | Comments |
|---|---|
| Off | |
| 1st switch press | Initial 2-3 sec. self-test then normal mode low intensity |
| 2nd switch press | normal mode medium intensity |
| 3rd switch press | normal mode high intensity |
| 4th switch press | off mode |
| Low battery | low battery on when battery = 3.5 $V_{dc}$ |
| Low battery 1st switch press | low battery off |
| Low battery 2nd switch press | low battery on |

1.3. Battery pack:
   1.3.1. The cap lamp is powered by a 8-cell lithium-ion battery
   1.3.2. $V_{out}$ battery for normal operation: 3.5 $V_{dc}$ to 4.2 $V_{dc}$
   1.3.3. $V_{out}$ for low battery conditions: 3.5 $V_{dc}$
   1.3.4. Capacity: 17.6 amp hours
   1.3.5. The battery pack contains a shutdown circuit that prevents the battery from discharging below 3.0 $V_{dc}$.

1.4. Operating power for normal mode high intensity at 25° C ambient at 4.0 $V_{dc}$:
   1.4.1. normal mode low intensity; 84 ma; 0.336 watts
   1.4.2. normal mode medium intensity; 248 ma; 0.992 watts
   1.4.3. spot mode high intensity; 374 ma; 1.50 watts

1.5. Circuit board (single driver) PCB0120-01 Rev PR2

1.6. Maximum LED currents (ma): LED1 = 120; LED2 = 160; LED3 = 80

**NOTE:** File **NCL-T-001-rev 5.xls** lists the primary files for GEN4

# GEN 5 Cap Lamp Overview
# Intended for Metal/Nonmetal Mining

1.1. Temperature range:
   1.1.1. Operational ambient temperature is 0° C to 40° C.

1.2. Functional requirements:
   1.2.1. The GEN 5 cap lamp uses three LEDs. The LED drive currents, in milliamps (ma), depend on the external switch and battery condition as listed in Table 2.

**Table 2 - The GEN 5 cap lamp functions**

| Condition | Comments |
|---|---|
| Off | |
| 1st switch press | Initial 2-3 sec. self-test then normal mode low intensity |
| 2nd switch press | normal mode high intensity |
| 3rd switch press | spot mode high intensity |
| 4th switch press | off mode |
| Low battery | low battery on when battery = 3.5 $V_{dc}$ |
| Low battery 1st switch press | low battery off |
| Low battery 2nd switch press | low battery on |

1.3. Battery pack:
   1.3.1. The cap lamp is powered by a 8-cell lithium-ion battery
   1.3.2. $V_{out}$ battery for normal operation: 3.5 $V_{dc}$ to 4.2 $V_{dc}$
   1.3.3. $V_{out}$ for low battery conditions: 3.5 $V_{dc}$
   1.3.4. Capacity: 17.6 amp hours
   1.3.5. The battery pack contains a shutdown circuit that prevents the battery from discharging below 3.0 $V_{dc}$.

1.4. Operating power for normal mode high intensity at 25° C ambient and 4.0 $V_{dc}$:
   1.4.1. normal mode low intensity; 64 ma; 0.256 watts
   1.4.2. normal mode high intensity; 373 ma; 1.49 watts
   1.4.3. spot mode high intensity; 375 ma; 1.50 watts

1.5. Circuit board (dual driver) PCB 0137-01 REV A

1.6. Maximum LED currents (ma): LED1 = 360; LED2 = 240; LED3 = 120

**NOTE:** File **NCL5-T-001-rev 1.xls** lists the primary files for GEN 5

# GEN 4E Cap Lamp Overview
# Intended for Coal or Metal/Nonmetal Mining

1.1. Temperature range:
   1.1.1. Operational ambient temperature is 0° C. to 40° C.

1.2. Functional requirements:
   1.2.1. The GEN 4E cap lamp uses three LEDs. The LED drive currents, in milliamps (ma), depend on the external switch and battery condition as listed by Table 3.

**Table 3 - The GEN 4E cap lamp functions**

| Condition | Comments |
|---|---|
| Off | |
| 1st switch press | Initial 2-3 sec. self-test then normal mode low intensity |
| 2nd switch press | normal mode high intensity |
| 3rd switch press | spot mode high intensity |
| 4th switch press | off mode |
| Low battery | low battery on when battery = 2.95 $V_{dc}$ |
| Low battery 1st switch press | low battery off |
| Low battery 2nd switch press | low battery on |

1.3. Battery:
   1.3.1. The cap lamp is powered by a K2 #26650EV lithium cell
   1.3.2. $V_{out}$ battery for normal operation: 3.2 $V_{dc}$
   1.3.3. $V_{out}$ for low battery conditions: 2.95 $V_{dc}$
   1.3.4. Capacity: 3.2 amp hours.

1.4. Operating power 25° C ambient and Vin = 3.2 $V_{dc}$:
   1.4.1. normal mode low intensity; 62 ma; 0.198 watts
   1.4.2. normal mode high intensity; 282 ma; 0.902 watts
   1.4.3. spot mode high intensity; 183 ma; 0.586 watts

1.5. Circuit board (dual driver) PCB 0137-01 REV A

1.6. Maximum LED currents (ma): LED1 = 360; LED2 = 240; LED3 = 120

**NOTE:** File **NCL4E-T-001-rev0.xls** lists the primary files for GEN4E

# GEN 5E Cap Lamp Overview
# Intended for Coal or Metal/Nonmetal Mining

1.1. Temperature range:
   1.1.1. Operational ambient temperature is 0° C. to 40° C.

1.2. Functional requirements:
   1.2.1. The GEN 5E cap lamp uses three LEDs. The drive currents in milliamps (ma) depend on the external switch and battery condition as listed by Table 4.

**Table 4 - The GEN 4E cap lamp functions**

| Condition | Comments |
|---|---|
| Off | |
| 1st switch press | Initial 2-3 sec. self-test then low mode low intensity |
| 2nd switch press | high mode intensity |
| 3rd switch press | spot only mode high intensity |
| 4th switch press | off mode |
| Low battery | low battery on when battery = 2.95 $V_{dc}$ |
| Low battery 1st switch press | low battery off |
| Low battery 2nd switch press | low battery on |

1.3. Battery:
   1.6.1. The cap lamp is powered by a K2 #26650EV lithium-ion cell
   1.3.1. $V_{out}$ battery for normal operation: 3.2 $V_{dc}$ to 3.3 $V_{dc}$
   1.3.2. $V_{out}$ for low battery conditions: 2.95 $V_{dc}$
   1.3.3. Capacity: 3.2 amp hours

1.4. Operating power at 25° C ambient at Vin = 3.2 $V_{dc}$:
   1.4.1. normal mode low intensity; 62 ma; 0.198 watts
   1.4.2. normal mode high intensity; 282 ma; 0.902 watts
   1.4.3. spot mode high intensity; 183 ma; 0.586 watts

1.5. Circuit board (dual driver) PCB 0137-01 REV A

1.6. Maximum LED currents (ma): LED1 = 360; LED2 = 240; LED3 = 120

**NOTE:** File **NCL5E-T-001-rev 1.xls** lists the primary files for GEN5E