ARMY RESEARCH LABORATORY

Metal Detector Battery Longevity Study

by Jennifer Mullins, Donald Porschet, and John Hopkins

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NOTICES

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14. ABSTRACT
We conducted a battery longevity study on seven metal detectors: the Vallon VMC1, Vallon VMH3CS, Garrett RECON-PRO AML-1000, MineLab F3, Foerster Minex 2FD 4.530, Scheibel Mini Mine Detector (MIMID), and the Ceia Compact Metal Detector (CMD). The test consisted of two separate phases: root mean square (RMS) current draw with associated low battery threshold determination and waveform capture of the source current and voltage for each unit. We ran additional tests to review the turn-on and turn-off waveforms for each unit. The service life of the system will vary according to the system's operating environment; quality and brand of batteries; operating conditions; and condition of battery storage. Based on our experiments, we determined that the Foerster Minex 2FD 4.530 will operate 56 h while the Ceia CMD will only function for 5 h per set of batteries. The remaining five mine detectors fell into the 10 to 30 h range with regard to operational longevity.

15. SUBJECT TERMS
Alkaline battery, metal detector, longevity

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1. Introduction

Metal detectors have long been used by the U.S. Army for functions ranging from mine detection to geologic field studies to infrastructure improvement projects. A complete set of lab tests were conducted by the U.S. Army Research Laboratory (ARL), Adelphi, MD, to classify the various units in terms of sensitivity, capability, ergonomics, and longevity. This report focuses on the experiments conducted to quantify each unit's operational longevity and presents all relative battery life results.

Seven metal detectors were selected to determine the approximate battery life expectancy for each system. The following systems were evaluated:

- Vallon VMC1, serial number (SN): 1251
- Vallon VMH3CS, SN: 9523
- Garrett RECON-PRO AML-1000, SN: 49400514
- MineLab F3, SN: N00617
- Foerster Minex 2FD 4.530, SN: 03316
- Scheibel Mini Mine Detector (MIMID), SN: 8227
- Ceia Compact Metal Detector (CMD), SN: 20814042051

Normalization of each system was provided by Duracell Alkaline Manganese Dioxide (Coppertop) batteries operating at an ambient temperature of 21 °C. Although there was slight variation in sourced power from the high to low end of the cell voltage, the difference was minimal in the context of this study. For this study, we assumed that the systems operated in a near constant power mode relative to the installed batteries.

The test consisted of two separate phases: a root mean square (RMS) current draw with an associated low battery threshold determination and a waveform capture of the source current and voltage for each unit. We ran additional tests to review the turn-on and turn-off waveforms for each unit. Due to the power-on/off duty cycle and the short startup duration, we determined that these events, although substantially higher in monitored current, would not contribute to the long-term power draw on each battery pack.

2. Experimental Setup

We used a standard Agilent, bench-top power supply to emulate each respective mine detector battery pack. Due to limited battery compartment accessibility in each of the detectors, we fabricated nylon battery pack mockups (figure 1) for each brand of detector. These mockups allowed the operator to manually source power while accurately measuring voltage and current during each phase of testing.

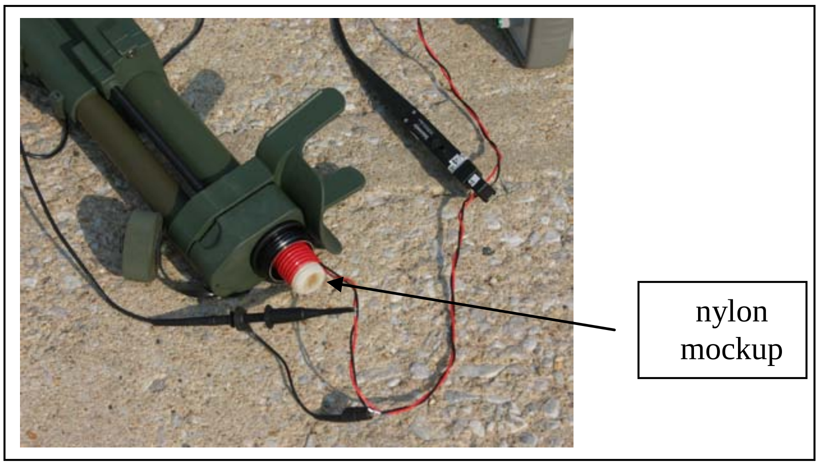

Figure 1. Example battery mockup.

Waveform data was collected with a Tektronix TDS3054 Oscilloscope, Tektronix TCP312 current probe, and a standard 10× oscilloscope probe (figure 2). All units tested during this phase of the evolution were supplied with fresh batteries and were operated at a nominal lab temperature of 21 °C. The waveforms are presented as a visual indicator of the load placed on each respective battery set.

Figure 2. Test apparatus.

3. Results

We made the following two assumptions: (1) the metal detector systems work under a constant power mode and (2) the power on/off and event detection-excited mode contribute minimally to the long-term power draw on the battery pack. Based on these assumptions, we calculated the power consumption for each system as a whole and for each individual battery cell using the nominal operation-unexcited mode data. Figures 3 and 4 show the results of these calculations, respectively.

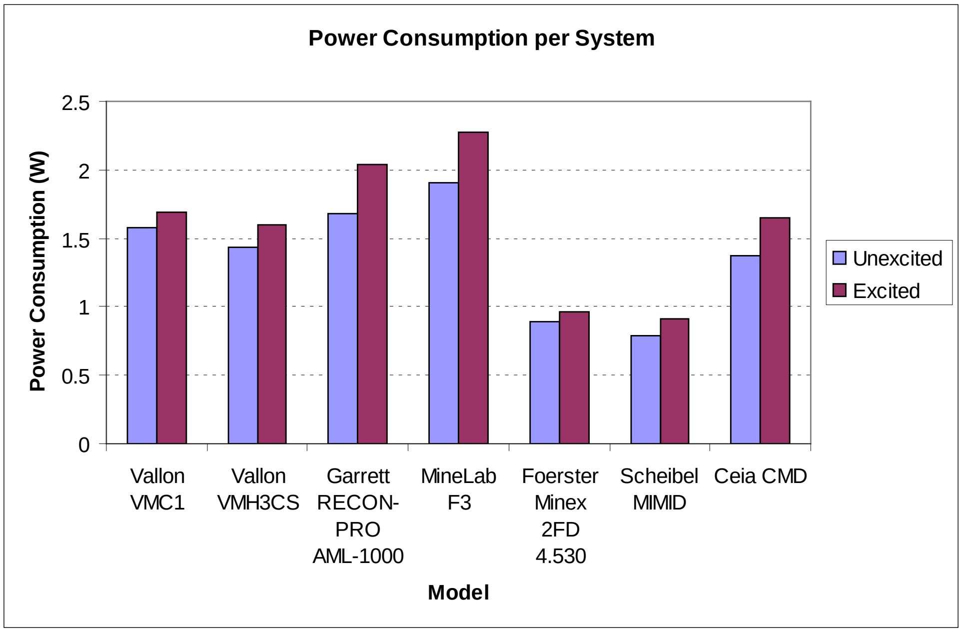

Figure 3. Power consumption per system.

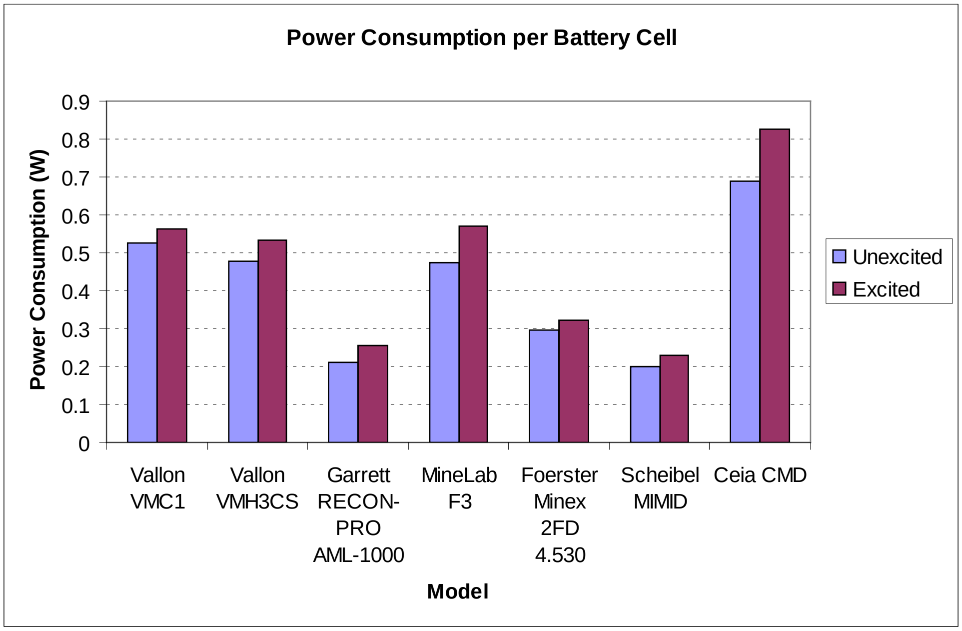

Figure 4. Power consumption per battery cell.

Using the power consumption per battery calculated in this study, we calculated the approximate battery service life expectancy per system. We normalized this life expectancy using Duracell Alkaline Manganese Dioxide (Coppertop) batteries as well as the typical discharge characteristics at 21 °C provided by Duracell. Figure 5 shows the approximate service life expectancies.

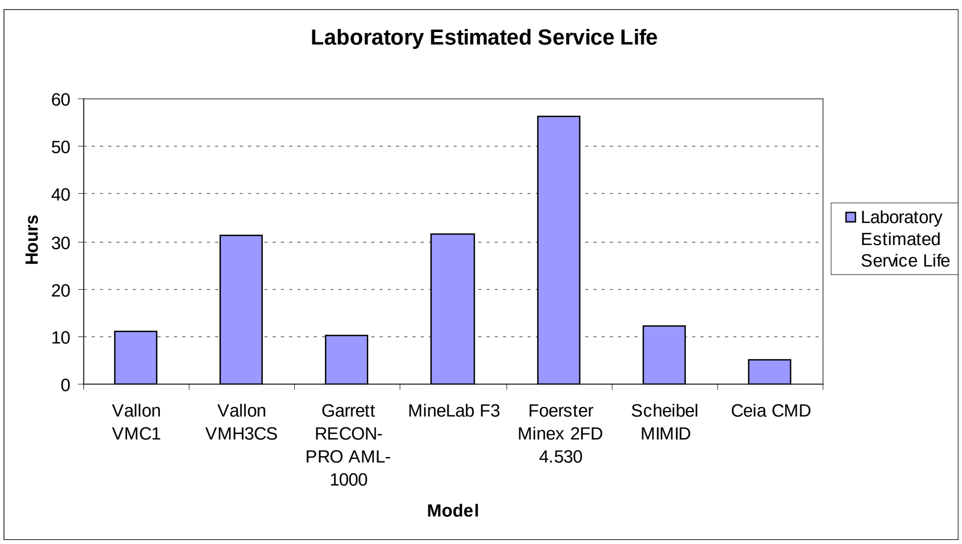

Figure 5. Estimated operational time per set of batteries.

Note: Normalized to the Duracell Coppertop brand.

Additionally, we compared the number, weight, volume, and cost of batteries if all seven metal detectors were operated for 50 h using commonly available Duracell Alkaline-Manganese Dioxide (Coppertop) batteries. The results of these calculations are summarized in table 1 and further illustrated in figures 6 and 7.

Table 1. Operational breakdown for 50 h of use with Duracell Alkaline Manganese Dioxide (Coppertop) batteries.

Detector Model	Vallon VMC1	Vallon VMH3CS	Garrett RECON-PRO AML-1000	MineLab F3	Foerster Minex 2FD 4.530	Scheibel MIMID	Ceia CMD
Size	C-cell MN1400	D-cell MN1300	AA-cell MN1500	D-cell MN1300	D-cell MN1300	AA-cell MN1500	C-cell MN1400
Total No. of Batteries Required	15	6	40	8	3	20	20
Total Weight (kg)	1.04	0.83	0.96	1.11	0.42	0.48	1.38
Total Volume (cubic cm)	404	338	336	451	169	168	538
Approximate Cost per Battery	$1.92	$2.61	$0.83	$2.61	$2.61	$0.83	$1.92
Total Cost ($)	$28.74	$15.66	$33.20	$20.88	$7.83	$16.60	$38.33

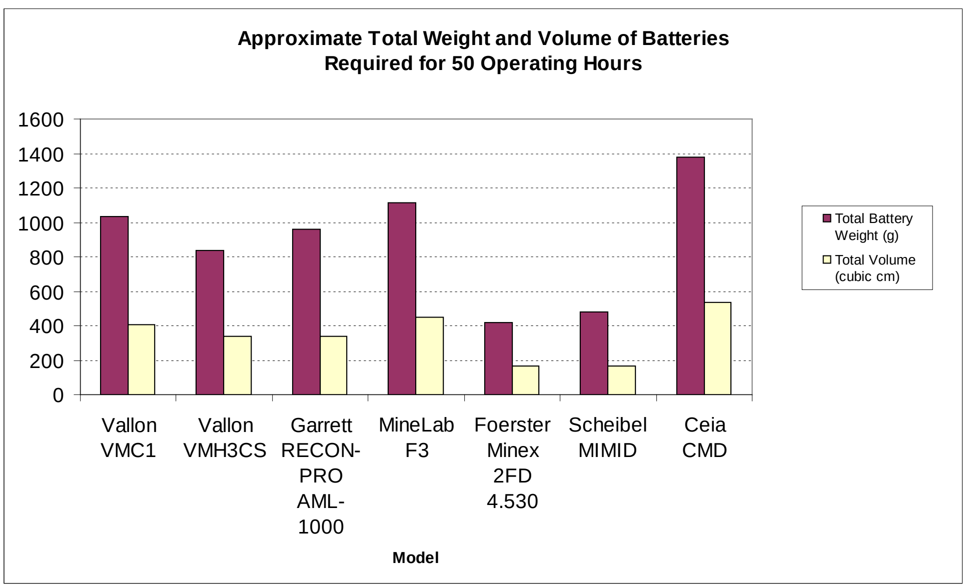

Figure 6. Total weight and volume of batteries required to operate each model for 50 h.

Note: Normalized to the Duracell Coppertop brand.

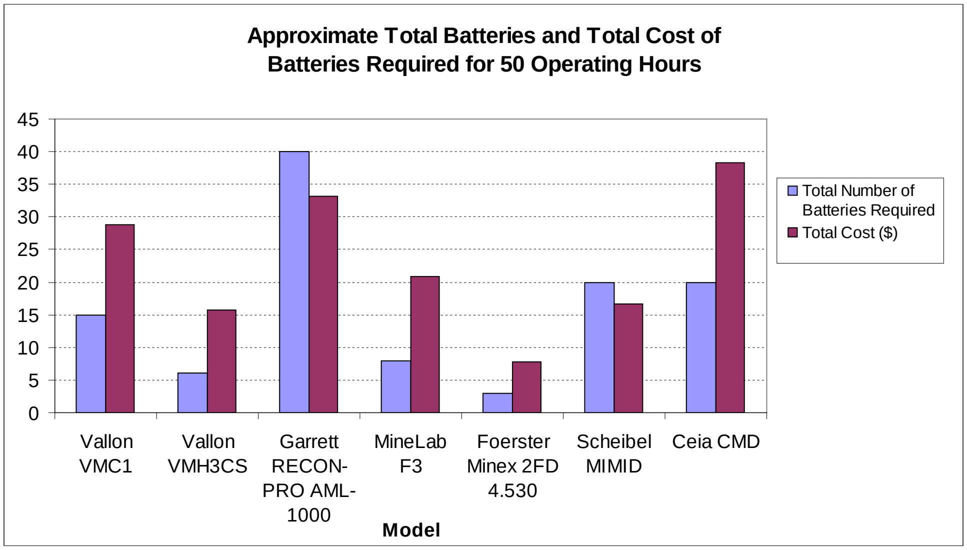

Figure 7. Total number of batteries and total cost of the batteries required to operate each model for 50 h.

Note: Normalized to the Duracell Coppertop brand.

4. Conclusion

As the weight burden on both the mounted and dismounted Soldier in the field increases, all systems are undergoing greater scrutiny with regard to size, weight, and power. All man-portable electronic systems must not only perform at optimal levels, but must do so with a minimum number of batteries. This study provided one piece of relevant data required to assess metal detectors and determine the best system for deployed units in various field of operation.

In this study, we estimated the battery life expectancy for seven metal detectors using Duracell Alkaline Manganese Dioxide (Coppertop) batteries. Generally, the service life of the system will vary according the system's operating environment; quality and brand of batteries; operating conditions; and condition of battery storage. We determined that the Foerster Minex 2FD 4.530 has the longest estimated service life, 56 h per set of batteries. The Ceia CMD had the shortest estimated service life, only 5 h per set of batteries. The Vallon VMH3CS and MineLab F3 demonstrated similar estimated service lives at 31 and 32 h per set of batteries, respectively. The Vallon VMC1, Garrett RECON-PRO AML-1000, and Scheibel MIMID displayed estimated service lives ranging from 10 to 12 h per set of batteries.

5. References

1. House of Batteries Web site. Duracell Coppertop, MN1300, Size: D (LR50), Alkaline-Manganese Dioxide Batteries, Duracell: Bethel, CT, August 2006. http://www.houseofbatteries.com/pdf/MN1300 (accessed 28 October 2009).
2. House of Batteries Web site. Duracell Coppertop, MN1400, Size: C (LR14), Alkaline-Manganese Dioxide Batteries, Duracell: Bethel, CT, August 2006. http://www.houseofbatteries.com/pdf/MN1400 (accessed 28 October 2009).
3. House of Batteries Web site. Duracell Coppertop, MN1500, Size: AA (LR6), Alkaline-Manganese Dioxide Batteries, Duracell: Bethel, CT, August 2006. 28 October 2009. http://www.houseofbatteries.com/pdf/MN1500 (accessed 28 October 2009).

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Appendix A. Voltage and Current Graphs: Ceia CMD

Figures A-1 through A-4 show the voltage and current graphs for the Ceia CMD.

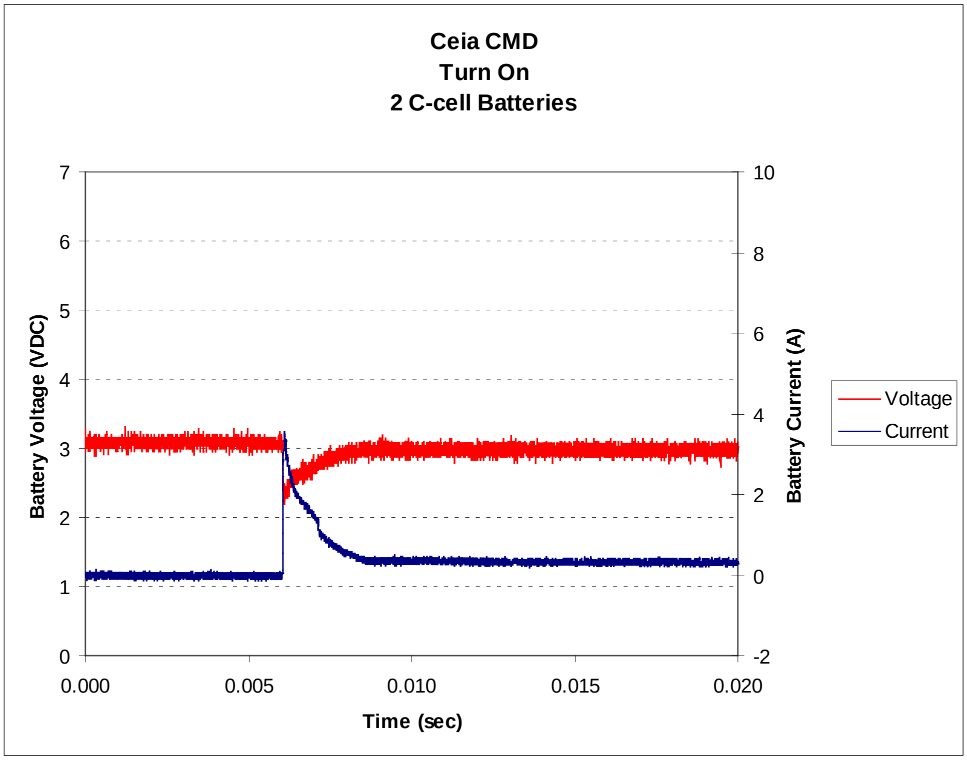

Figure A-1. Ceia CMD turn-on for two C-cell batteries.

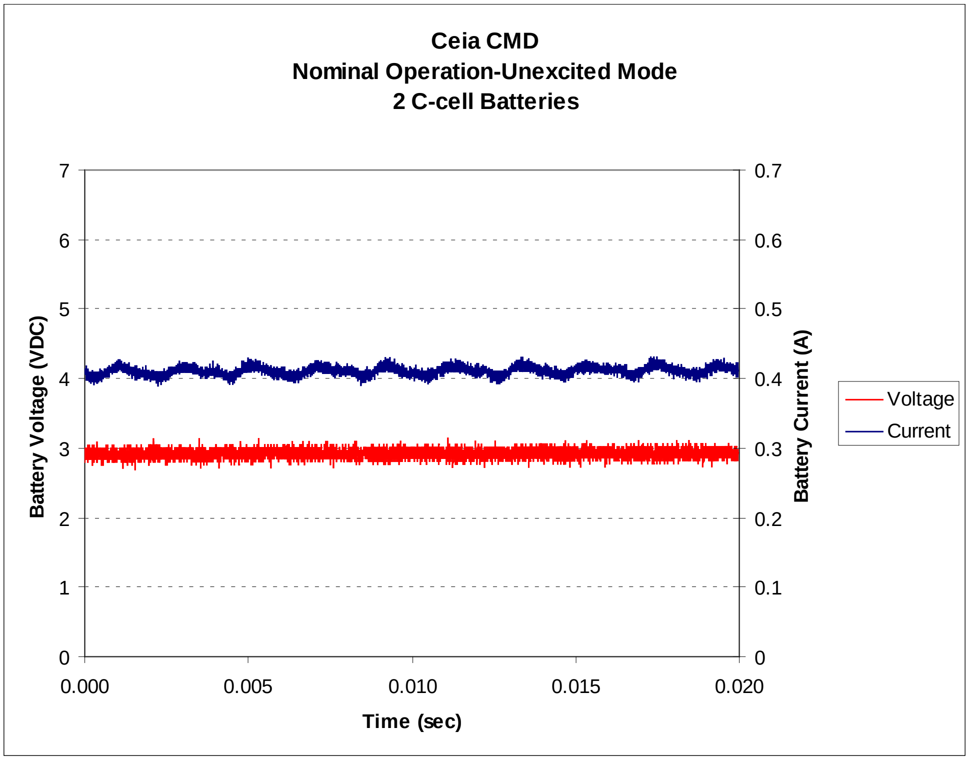

Figure A-2. Ceia CMD nominal operation-unexcited mode for two C-cell batteries.

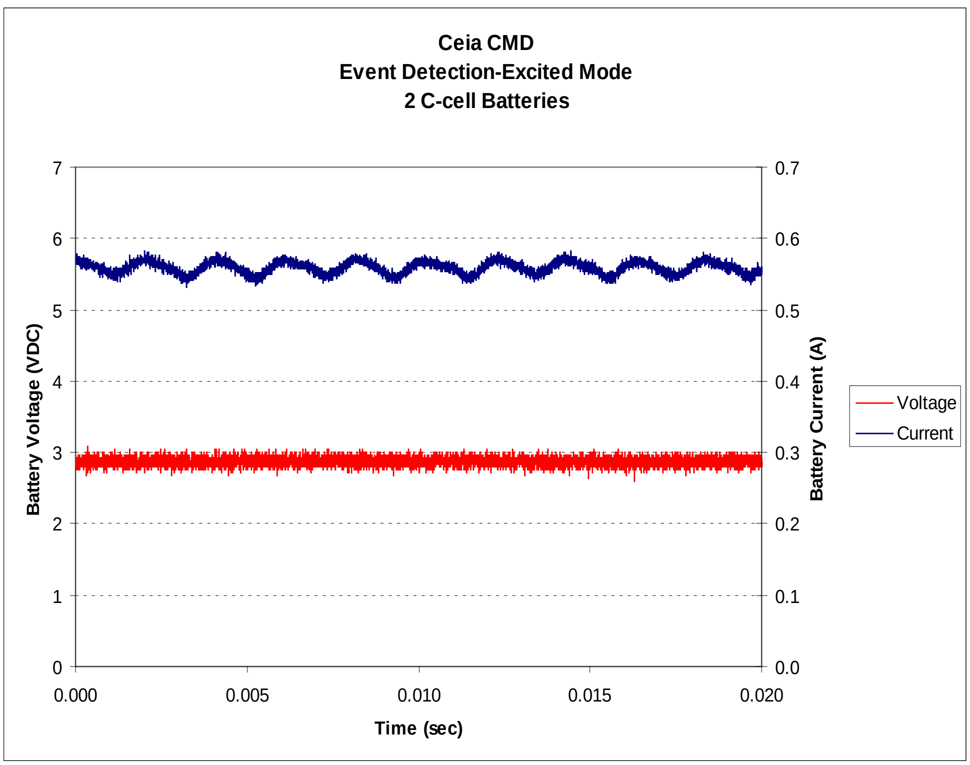

Figure A-3. Ceia CMD event detection-excited mode for two C-cell batteries.

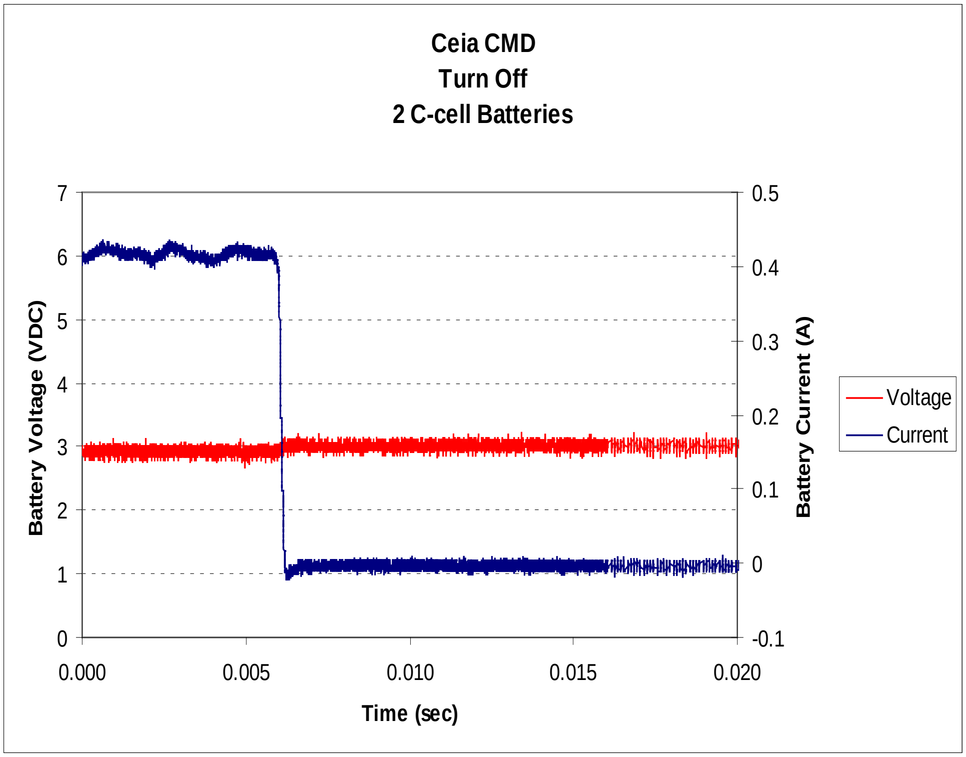

Figure A-4. Ceia CMD turn-off for two C-cell batteries.

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Appendix B. Voltage and Current Graphs: Foerster Minex 2FD 4.530

Figures B-1 through B-3 show the voltage and current graphs for the Foerster Minex 2FD 4.530.

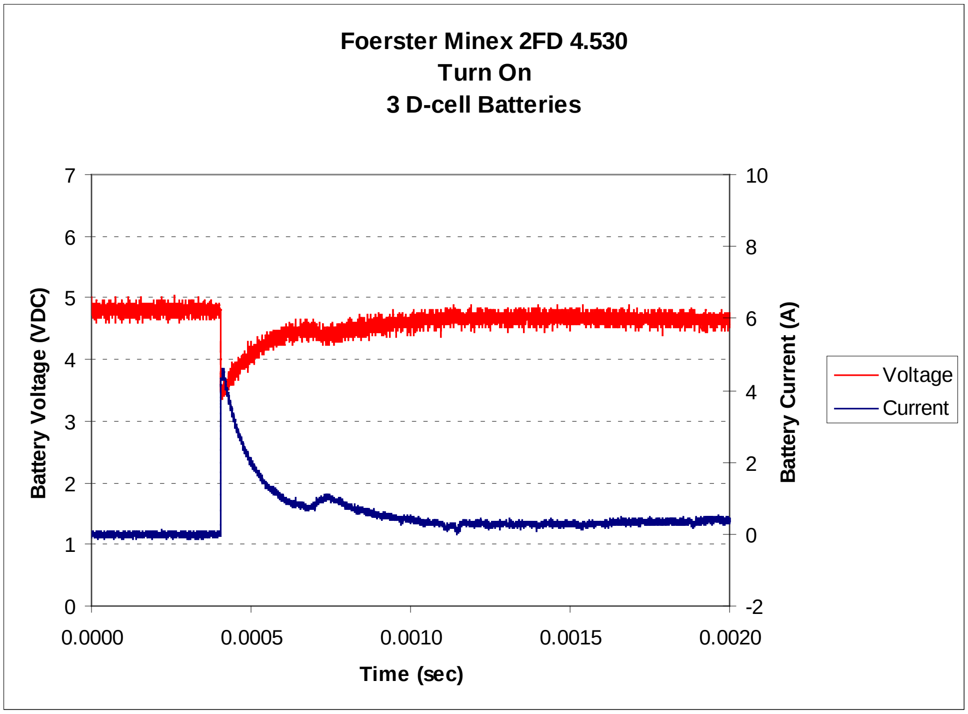

Figure B-1. Foerster Minex 2FD 4.530 turn-on for three D-cell batteries.

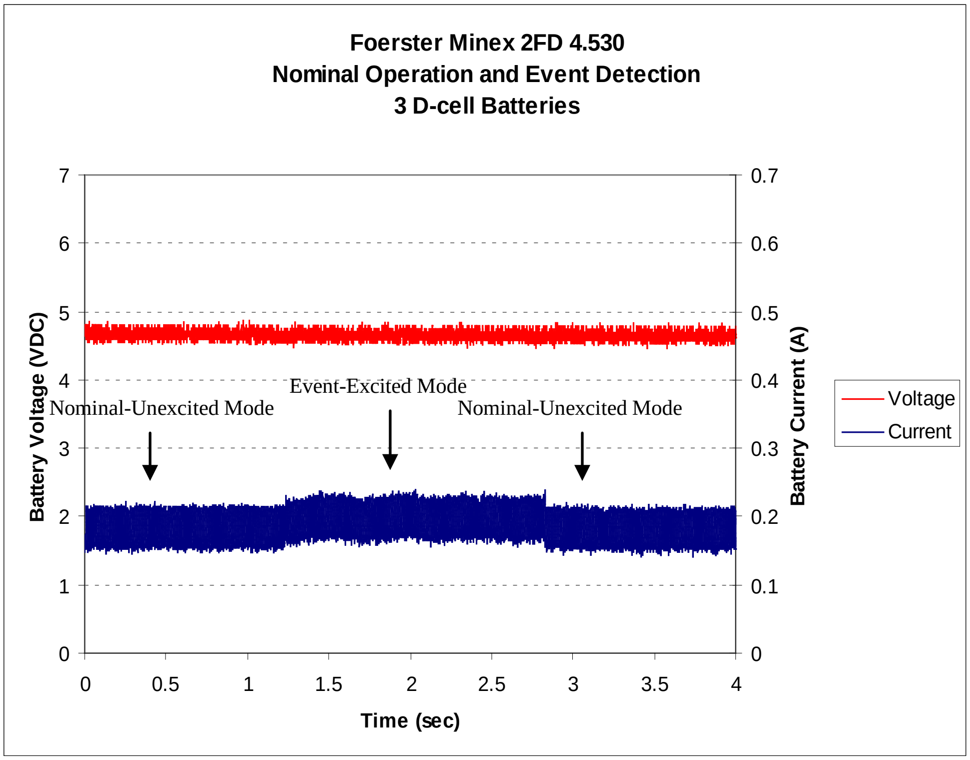

Figure B-2. Foerster Minex 2FD 4.530 nominal operation and event detection for three D-cell batteries.

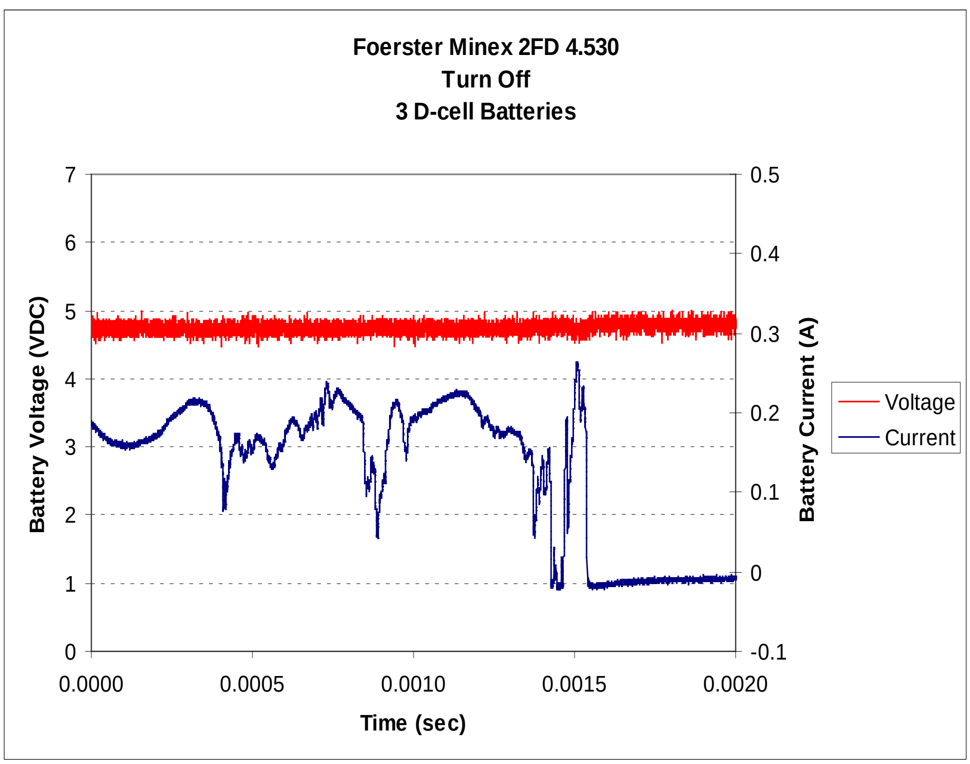

Figure B-3. Foerster Minex 2FD 4.530 turn-off for three D-cell batteries.

Appendix C. Voltage and Current Graphs: Garrett RECON-PRO AML-1000

Figures C-1 through C-4 show the voltage and current graphs for the Garrett RECON-PRO AML-1000. Note: The graphs show the battery voltage and battery current for one battery stack of four AA-cell batteries. The system operates with two identical battery stacks operating in parallel.

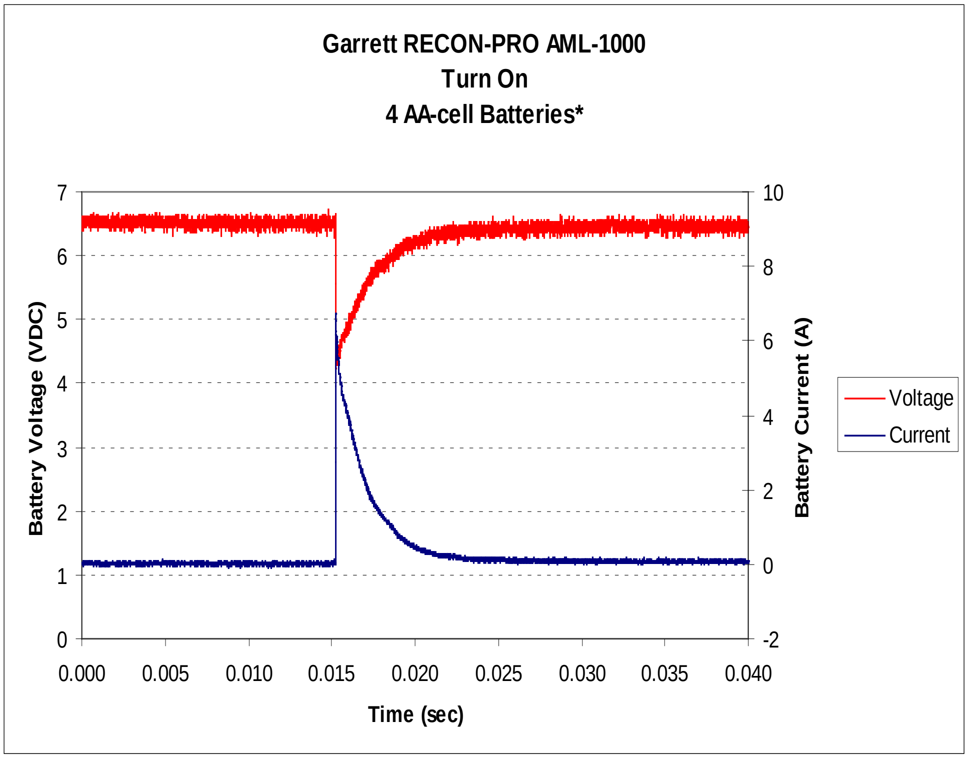

Figure C-1. Garrett RECON-PRO AML-1000 turn-on for four AA-cell batteries.

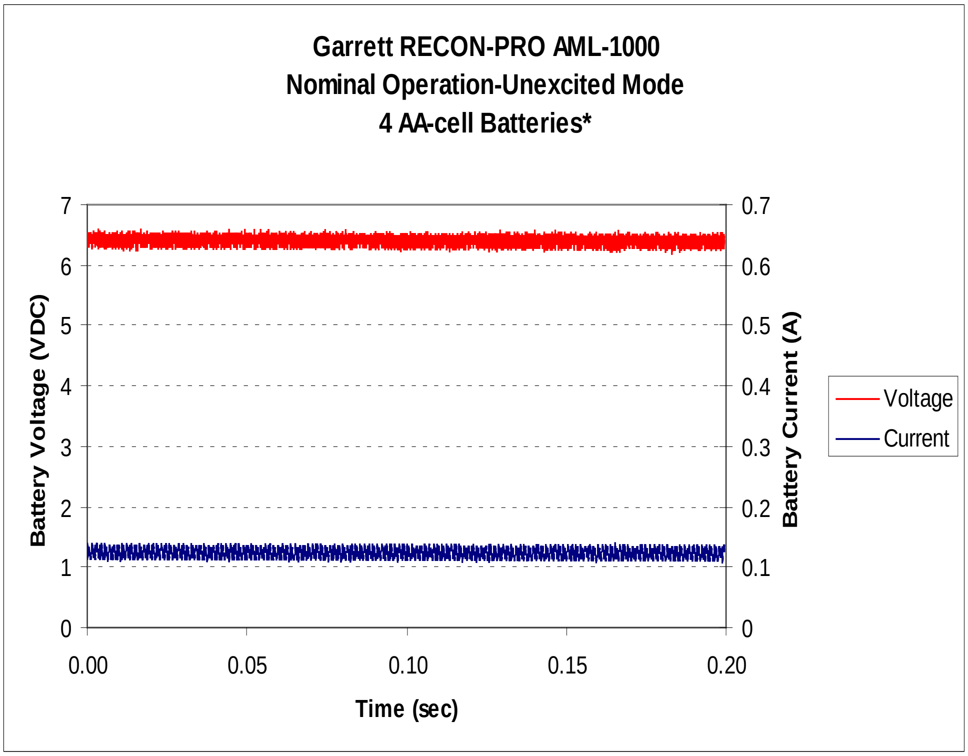

Figure C-2. Garrett RECON-PRO AML-1000 nominal operation-unexcited mode for four AA-cell batteries.

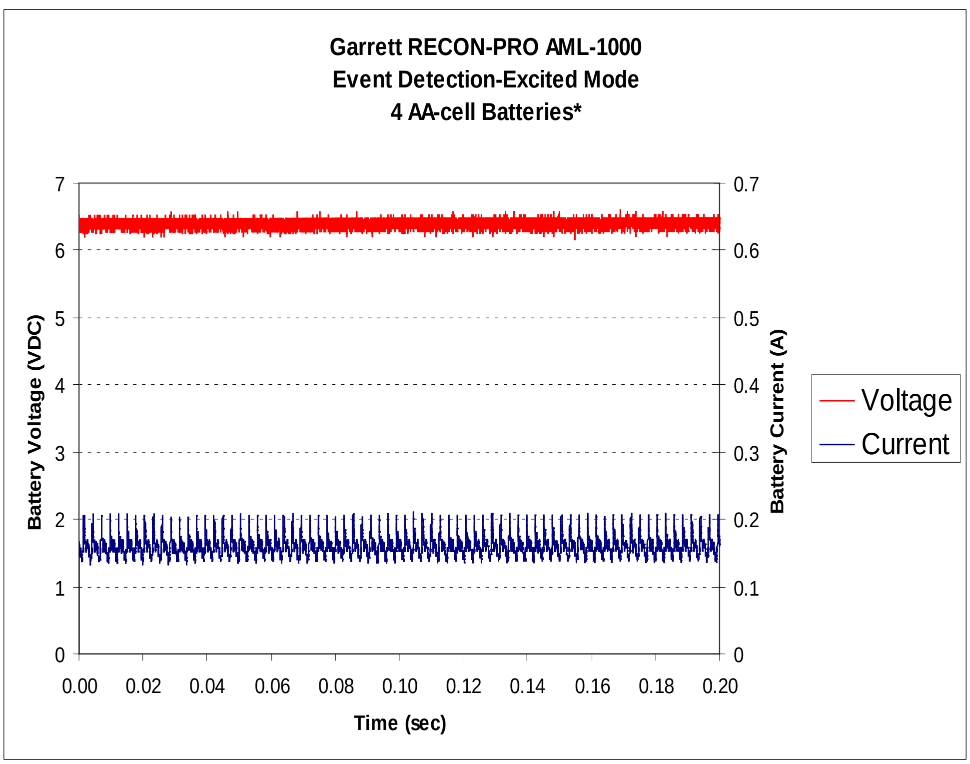

Figure C-3. Garrett RECON-PRO AML-1000 event detection-excited mode for four AA-cell batteries.

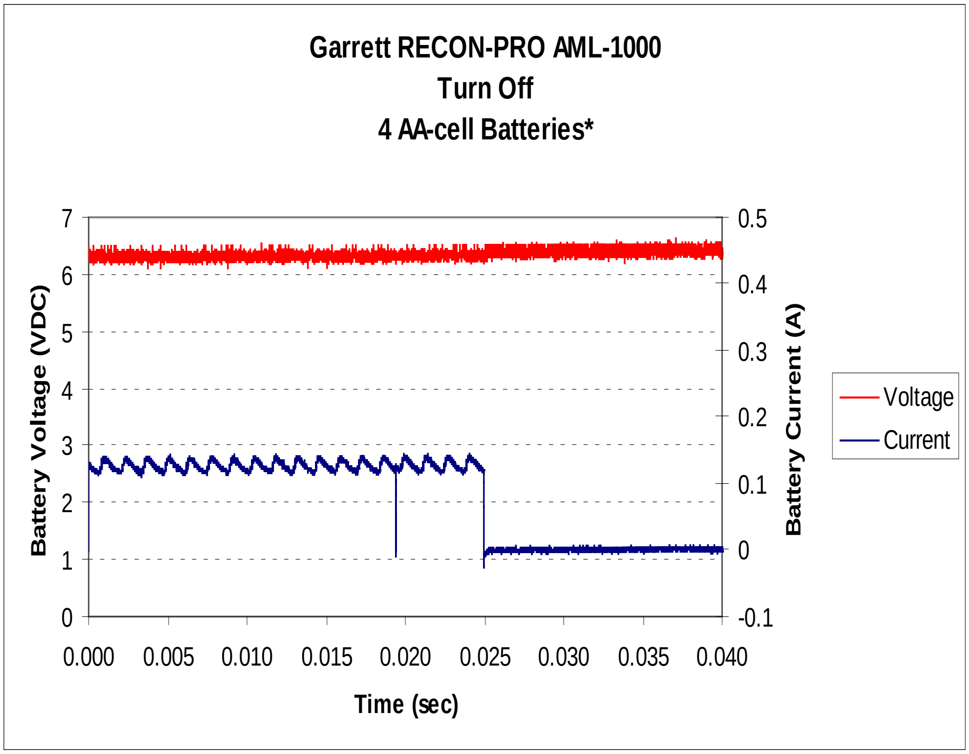

Figure C-4. Garrett RECON-PRO AML-1000 turn-off for four AA-cell batteries.

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Appendix D. Voltage and Current Graphs: MineLab F3

Figures D-1 through D-4 show the voltage and current graphs for the MineLab F3.

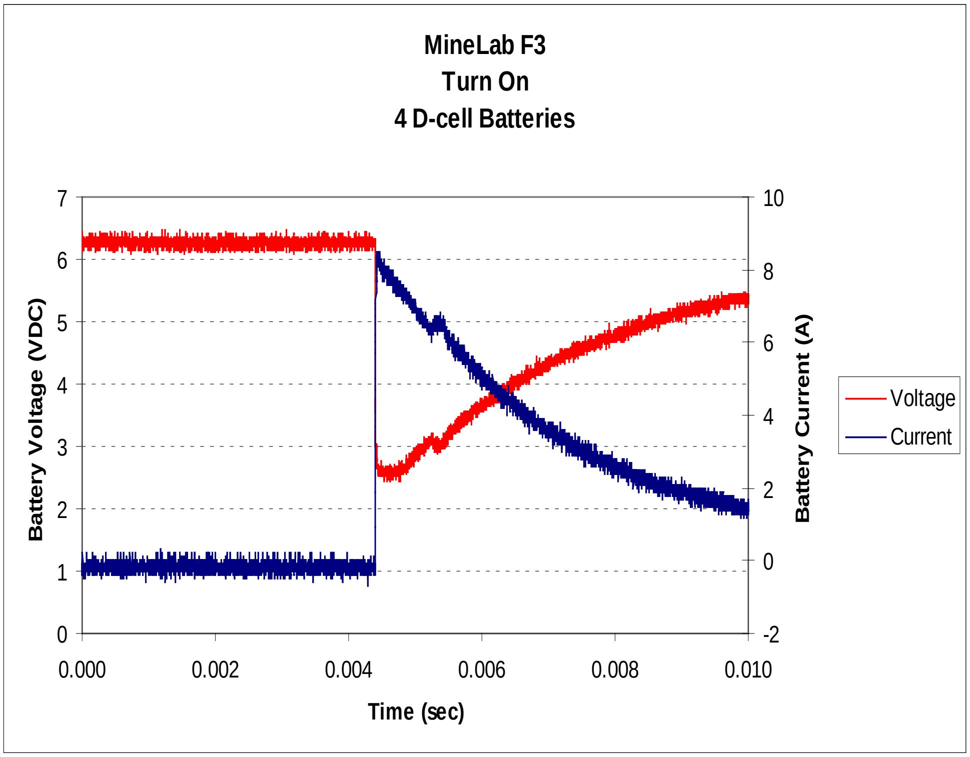

Figure D-1. MineLab F3 turn-on for four D-cell batteries.

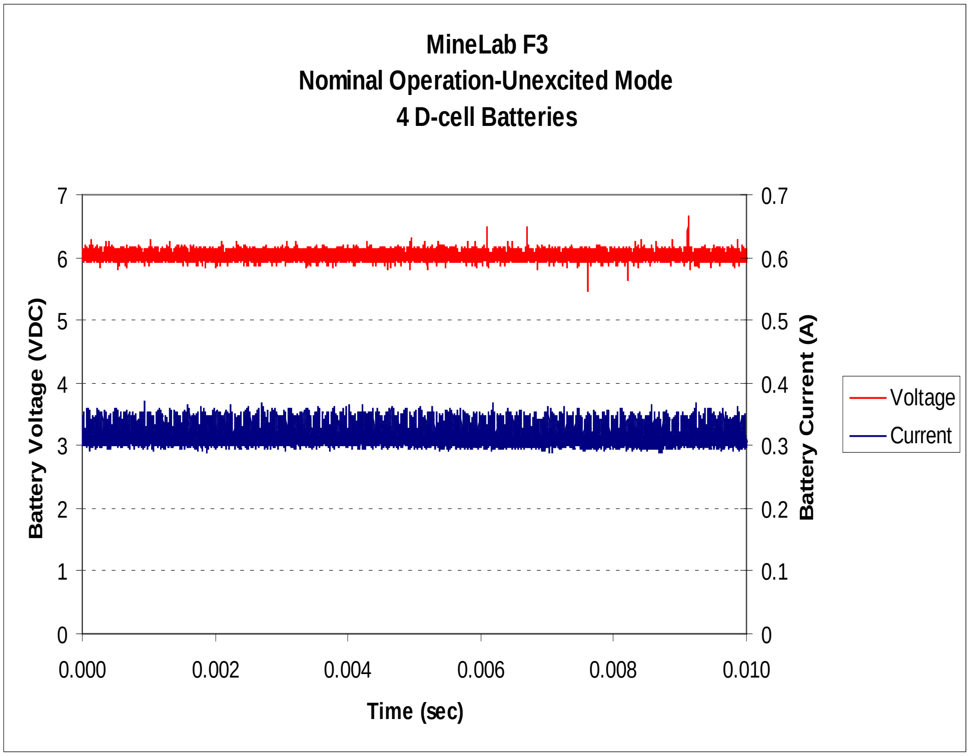

Figure D-2. MineLab F3 nominal operation-unexcited mode for four D-cell batteries.

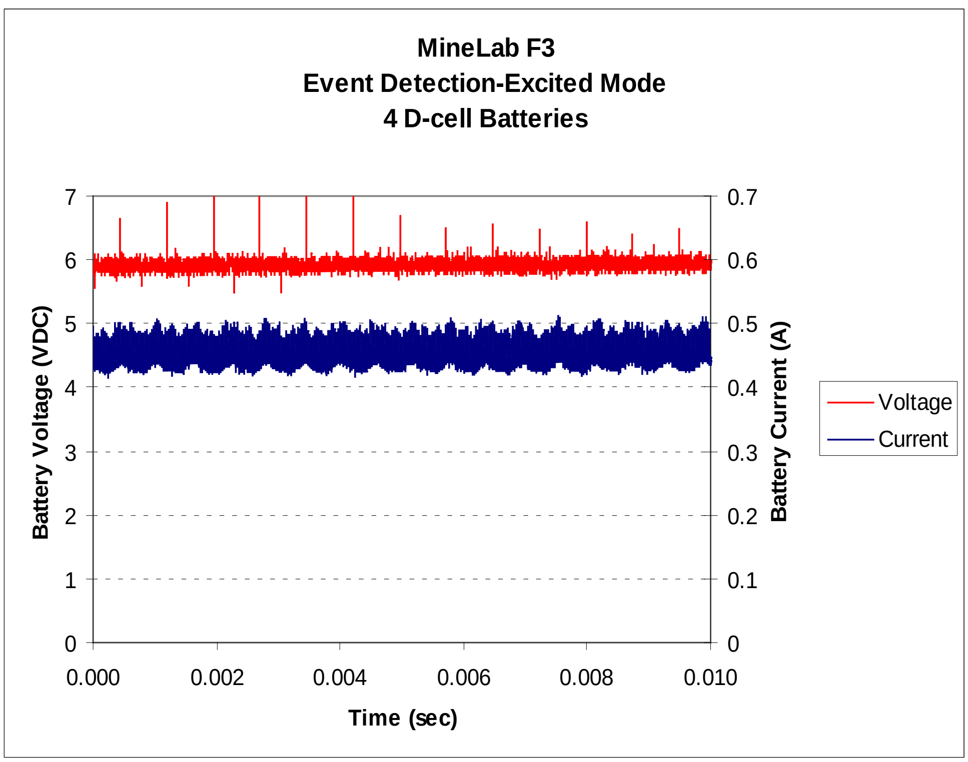

Figure D-3. MineLab F3 event detection-excited mode for four D-cell batteries.

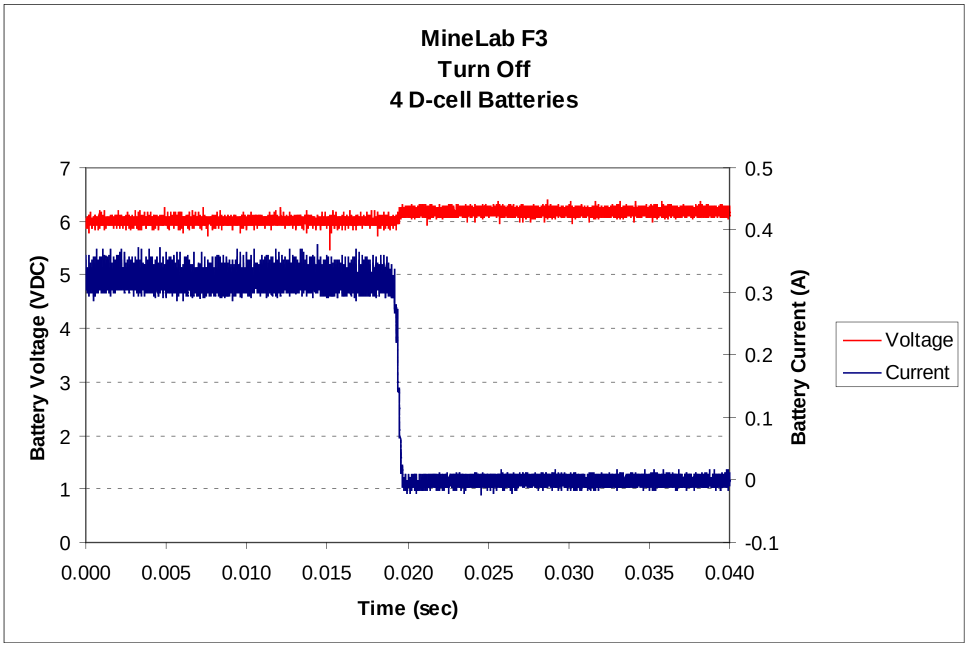

Figure D-4. MineLab F3 turn-off for four D-cell batteries.

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Appendix E. Voltage and Current Graphs: Scheibel MIMID

Figures E-1 through E-4 show the voltage and current graphs for the Scheibel MIMID.

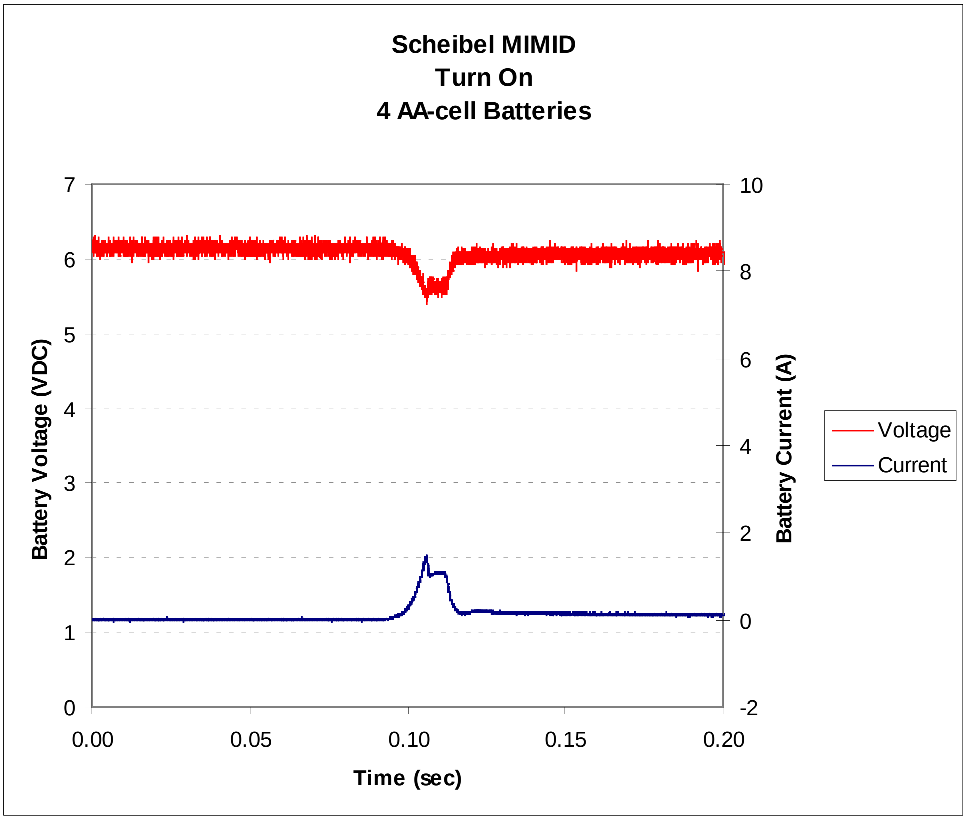

Figure E-1. Scheibel MIMID turn-on for four AA-cell batteries.

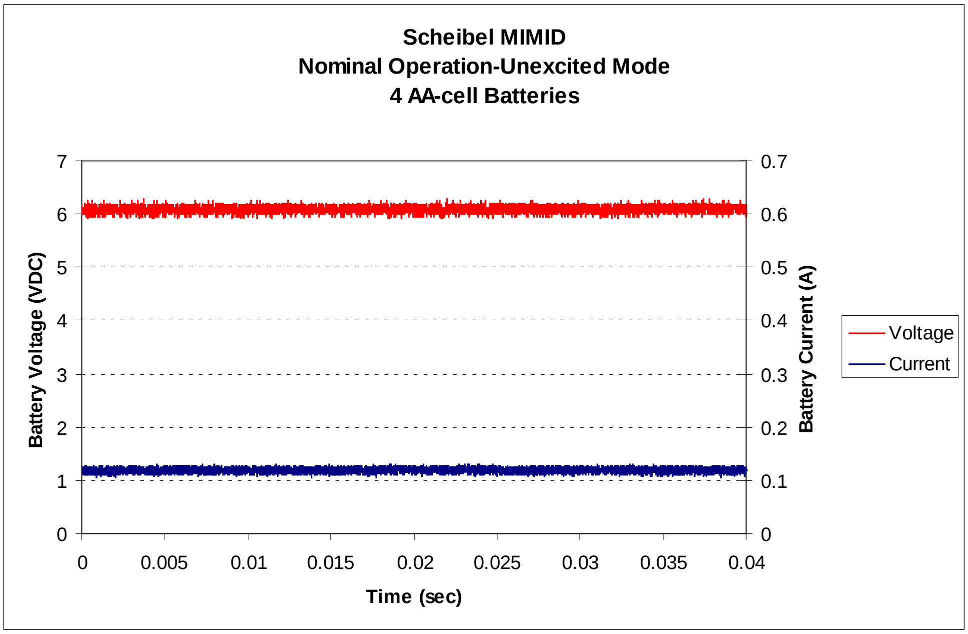

Figure E-2. Scheibel MIMID nominal operation-unexcited mode for four AA-cell batteries.

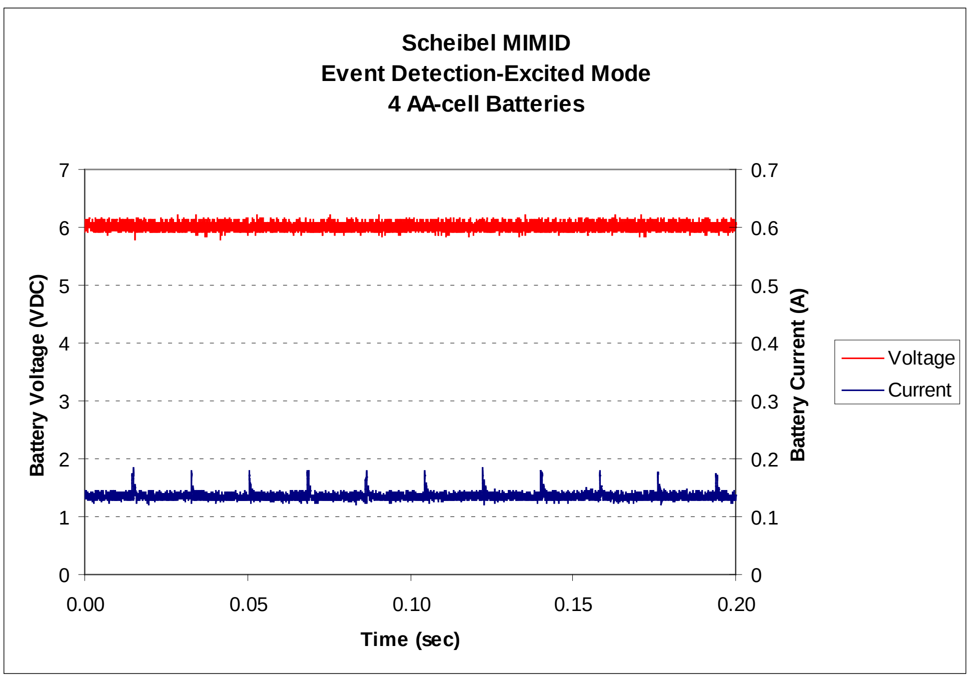

Figure E-3. Scheibel MIMID event detection-excited mode for four AA-cell batteries.

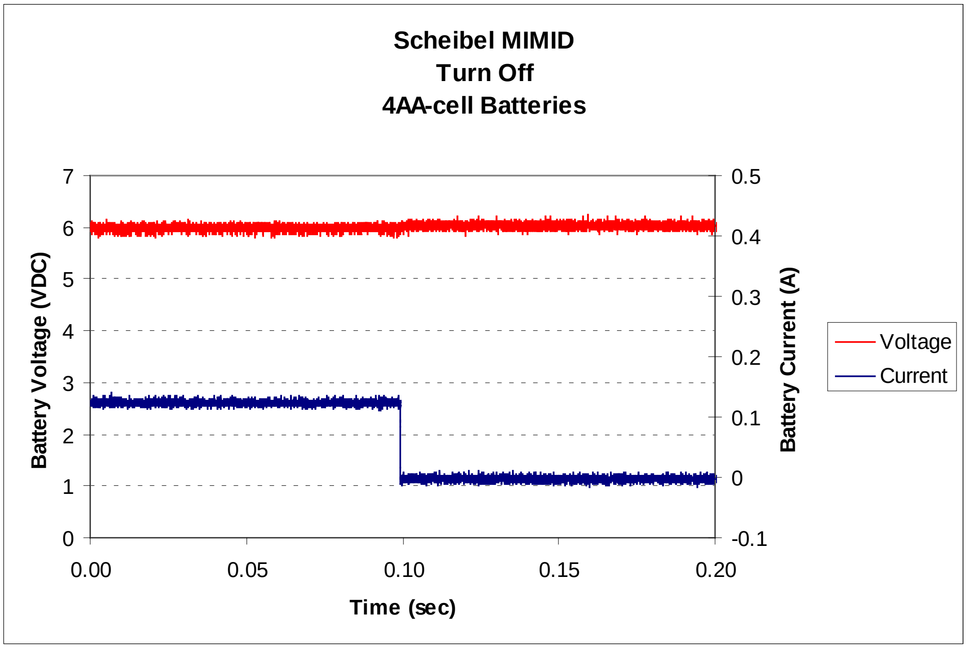

Figure E-4. Scheibel MIMID turn-off for four AA-cell batteries.

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Appendix F. Voltage and Current Graphs: Vallon VMC1

Figures F-1 through F-4 show the voltage and current graphs for the Vallon VMC1.

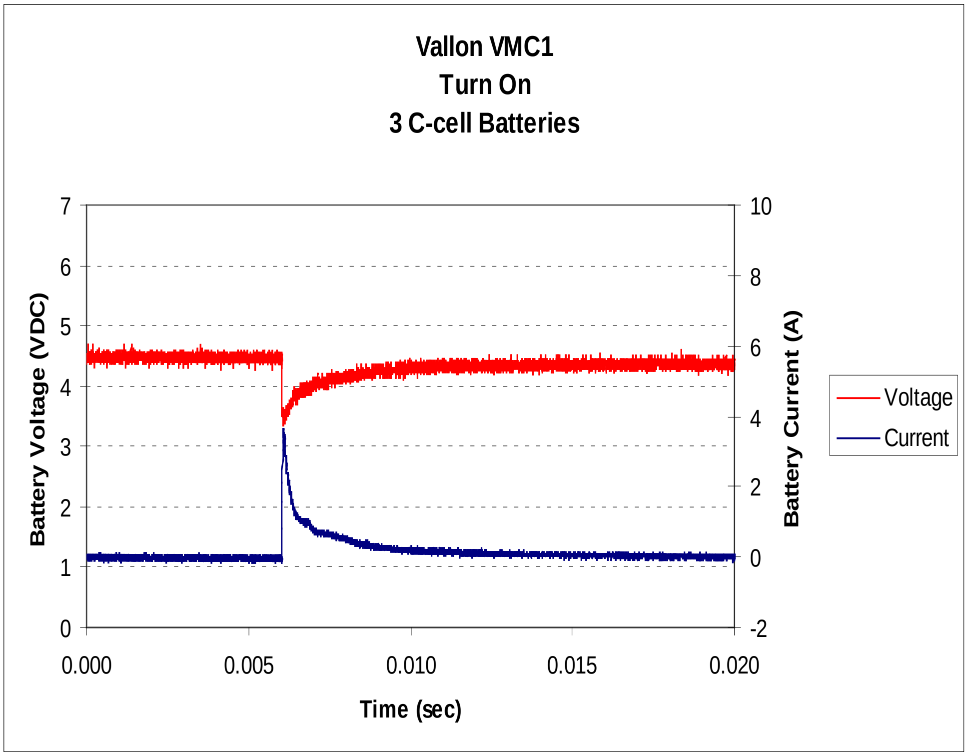

Figure F-1. Vallon VMC1 turn-on for three C-cell batteries.

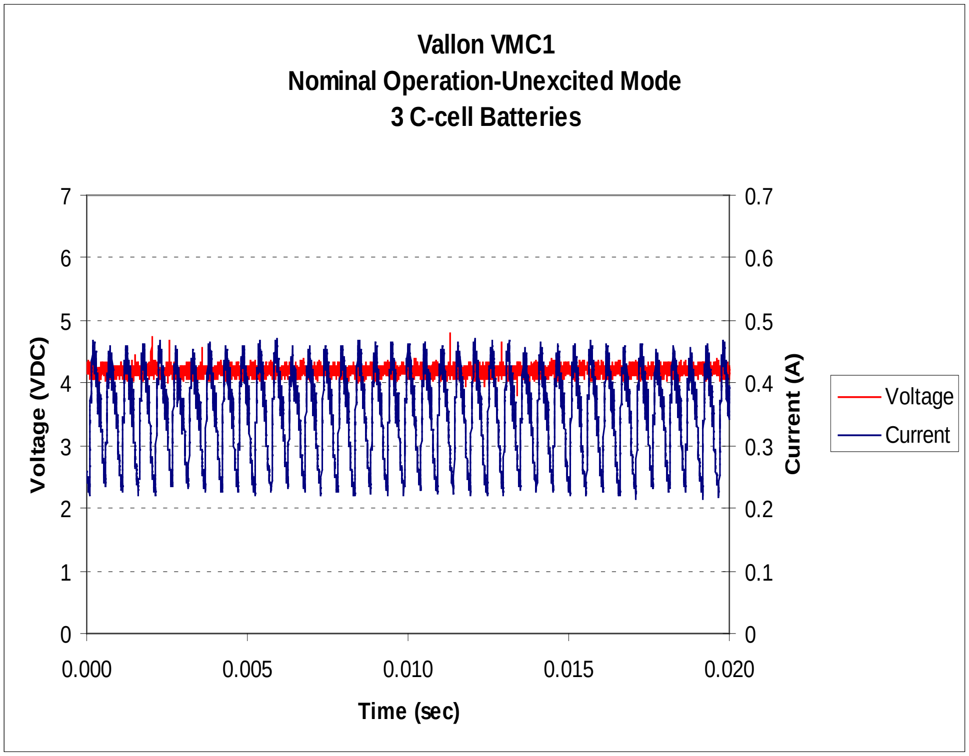

Figure F-2. Vallon VMC1 nominal operation-unexcited mode for three C-cell batteries.

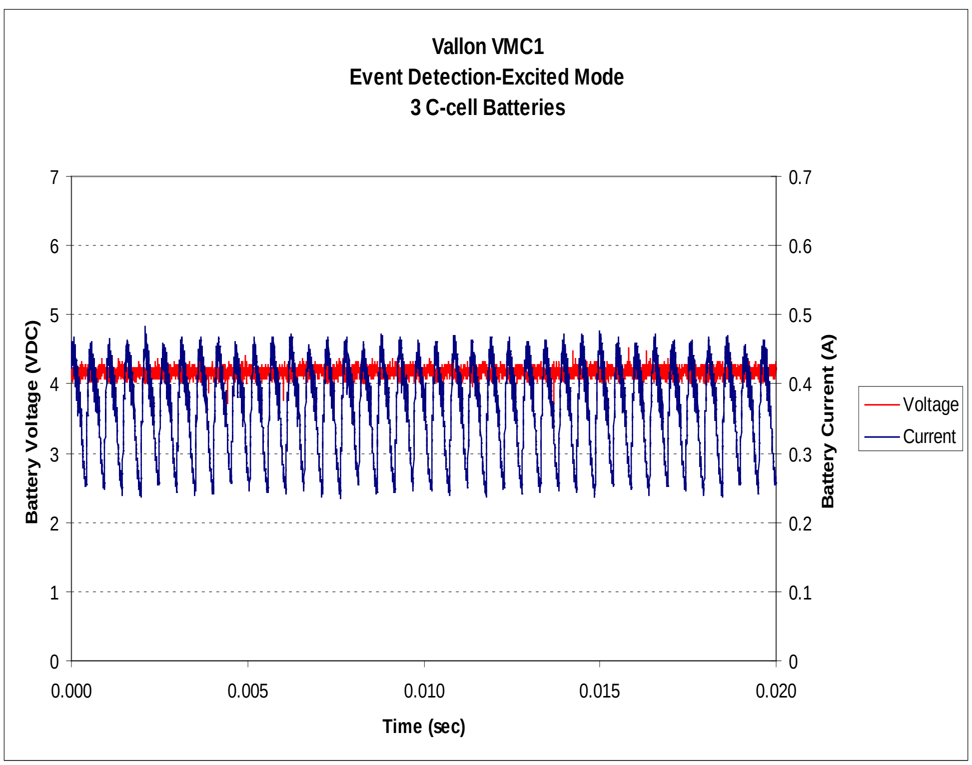

Figure F-3. Vallon VMC1 event detection-excited mode for three C-cell batteries.

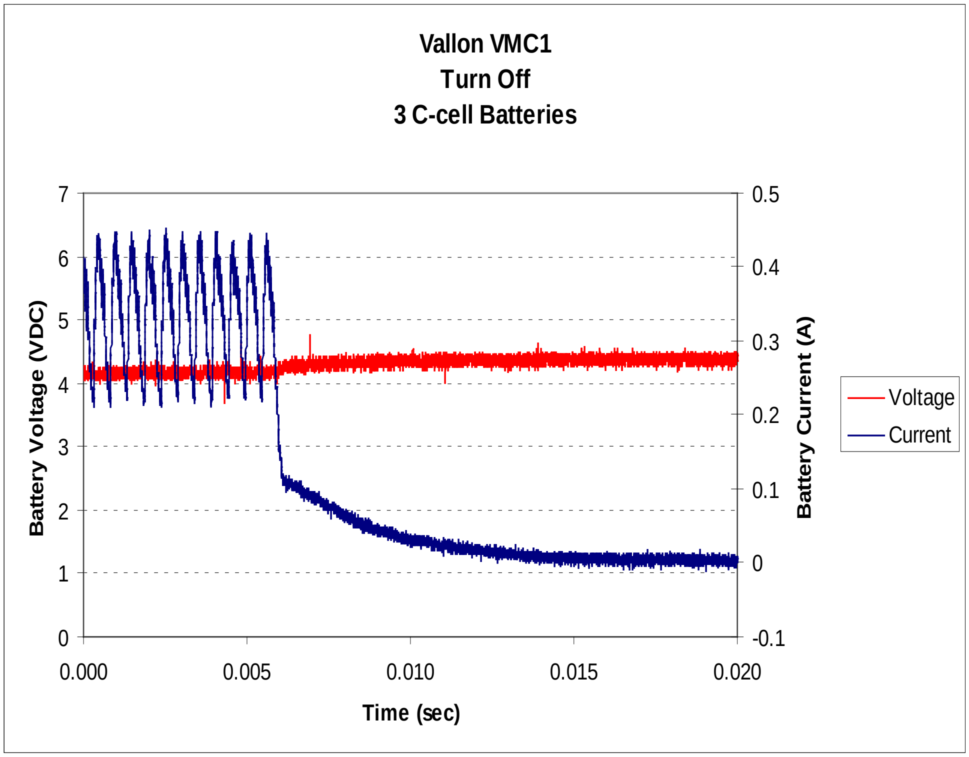

Figure F-4. Vallon VMC1 turn-off for three C-cell batteries.

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Appendix G. Voltage and Current Graphs: Vallon VMH3CS

Figures G-1 through G-4 show the voltage and current graphs for the Vallon VMH3CS.

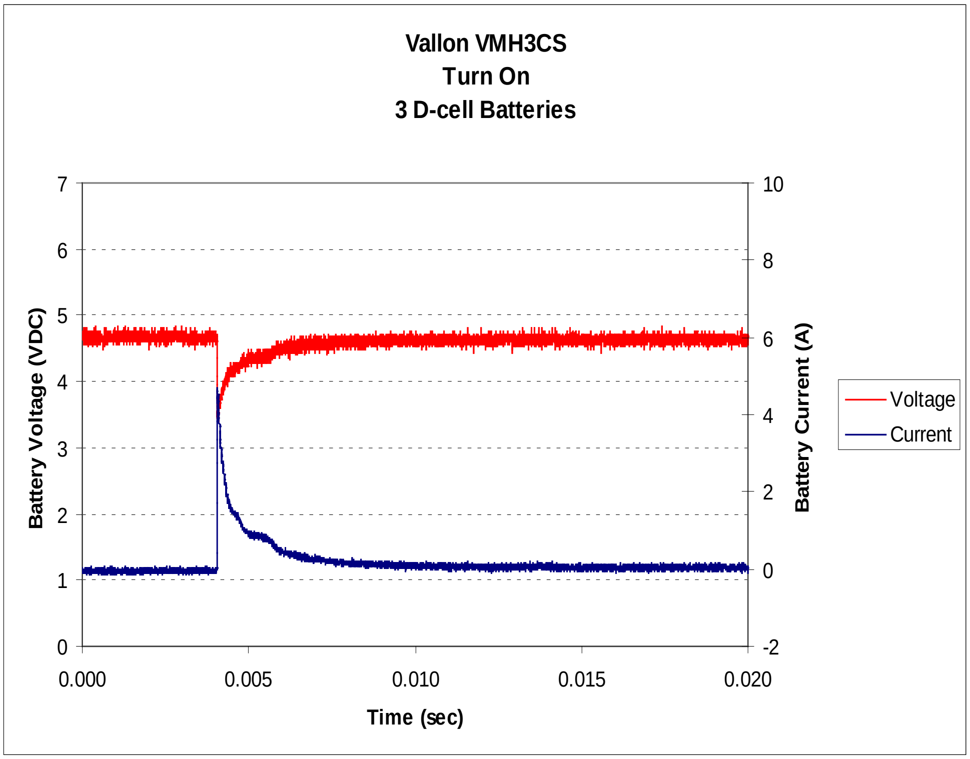

Figure G-1. Vallon VMH3CS turn-on for three D-cell batteries.

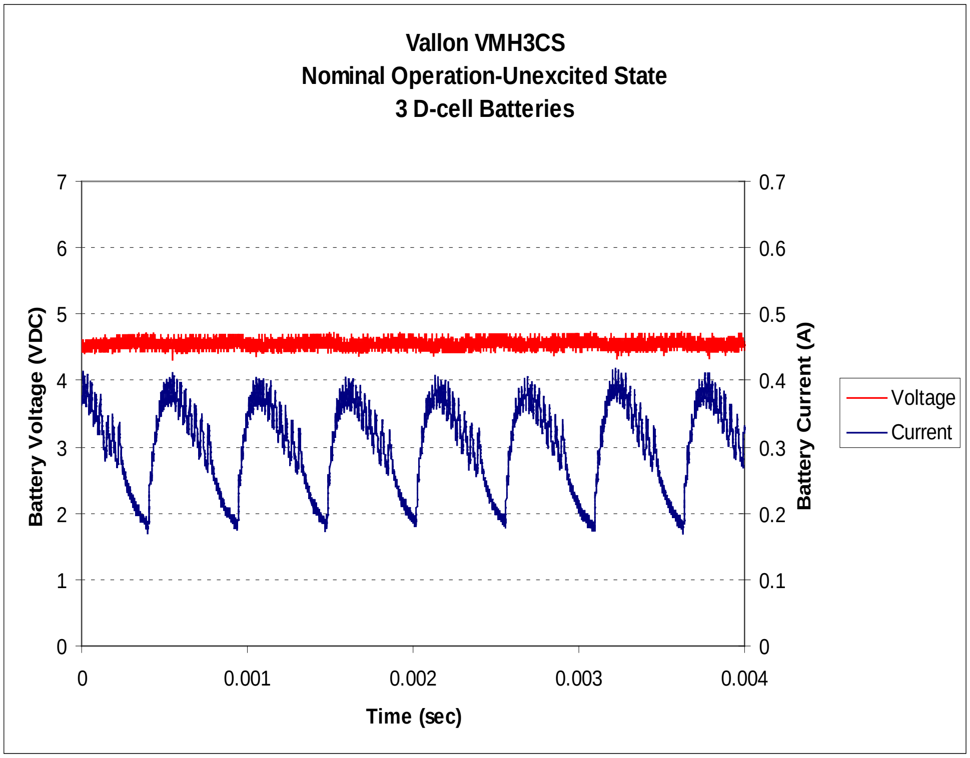

Figure G-2. Vallon VMH3CS nominal operation-unexcited mode for three D-cell batteries.

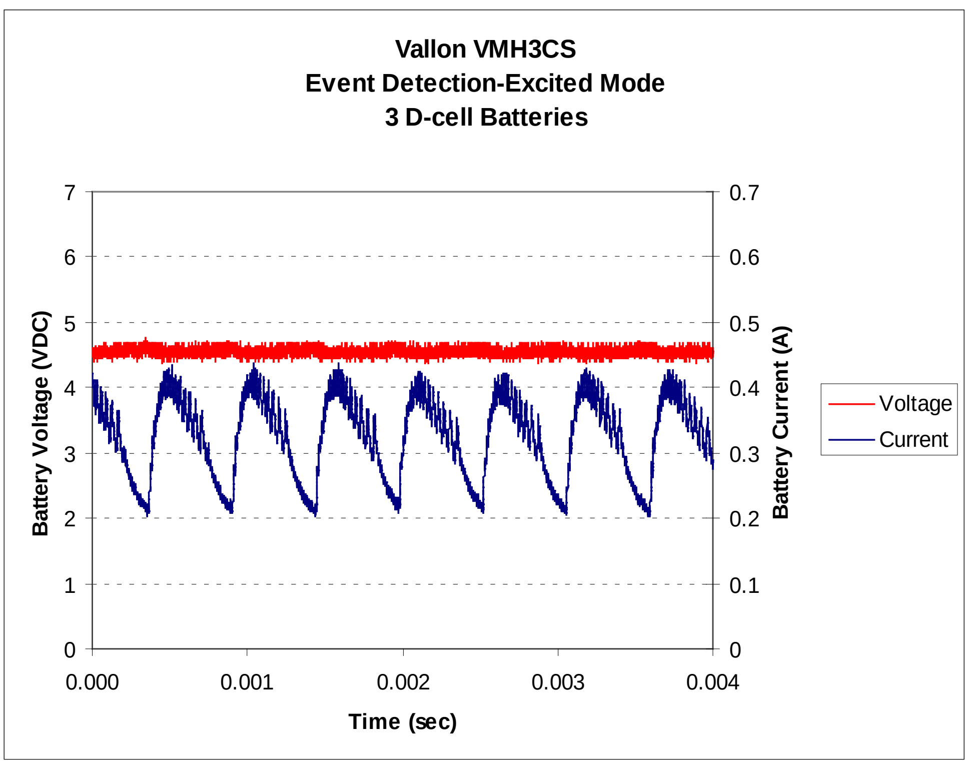

Figure G-3. Vallon VMH3CS event detection-excited mode for three D-cell batteries.

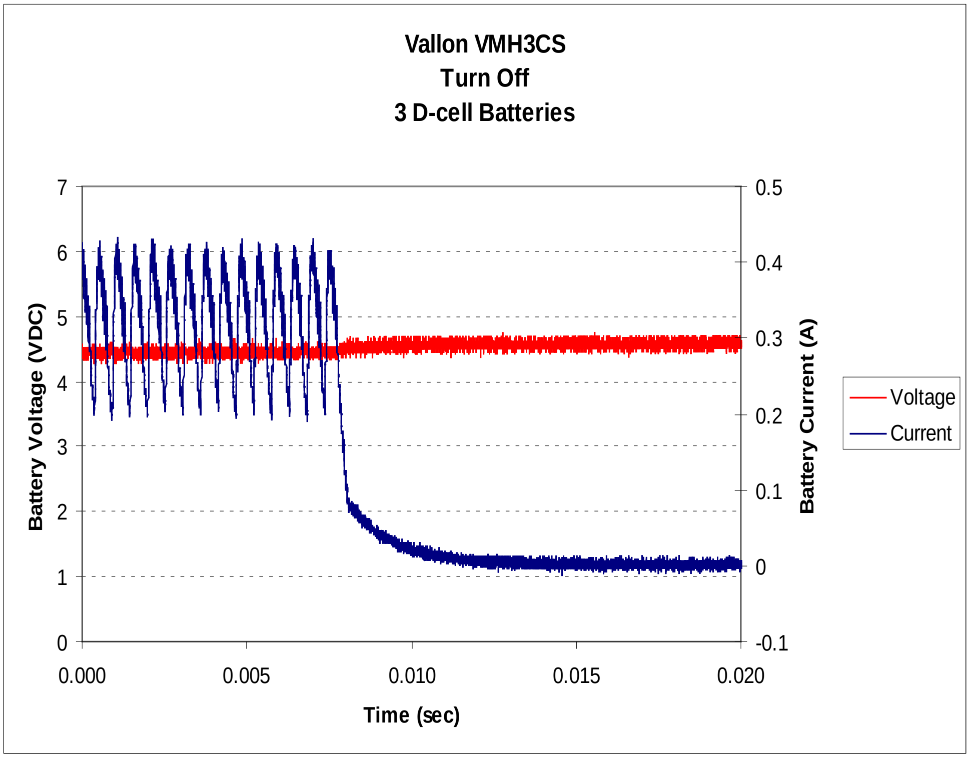

Figure G-4. Vallon VMH3CS turn-off for three D-cell batteries.

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