Multi-Option Fuze for Artillery (MOFA)
Post-launch Battery

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by

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Presentation Outline

- Introduction
- Description
- Battery Design
- Battery Performance
- Modular, Extendible Design
- Summary

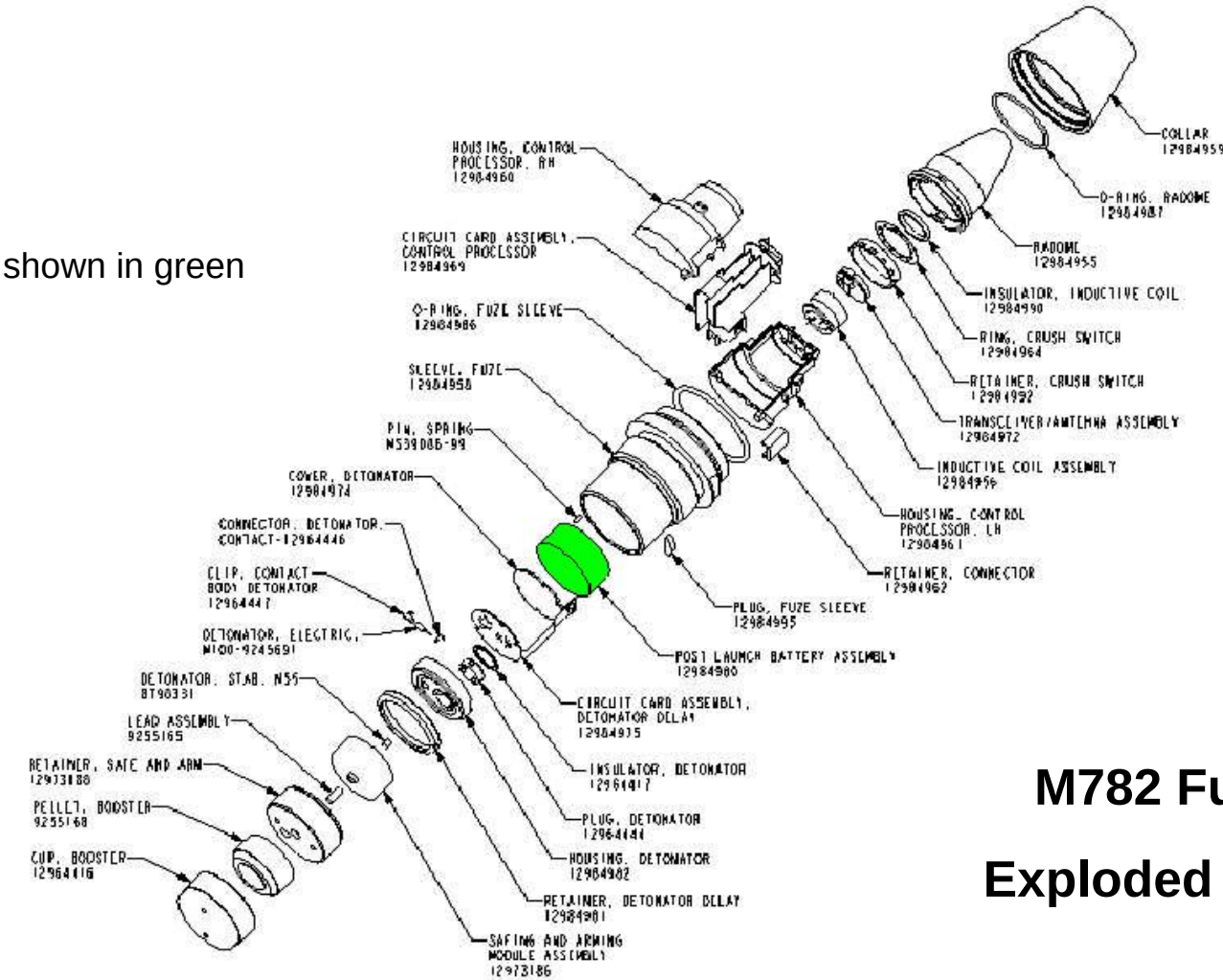
Introduction

- **The Multi-Option Fuze for Artillery (MOFA) required a reliable, low risk source of energy to power fuze functions.**
- **Three alternatives were considered:**
  - **A lead-fluoroboric acid multicell reserve battery based on HDL/ MOFA technology.**
  - **A multicell high rate lithium thionyl chloride battery with an activation mechanism similar to the PB-acid battery.**
  - **A thermal battery.**

Introduction Cont.

- **The thermal battery had significant technical concerns which removed it from consideration:**
  - **high projectile spin**
  - **the need for relatively fast activation**
  - **volume constraints**
- **The remaining alternatives were not as clearly differentiated so a weighing / scoring process was used for a more detailed evaluation of the decision criteria.**
- **The analysis resulted in scoring the lithium thionyl chloride approach higher than the lead acid approach.**
- **Major criteria affecting the results were:**
  - **environmental issues affecting the lead acid technology**
  - **limited availability of contractors to produce lead acid batteries**

Battery shown in green



M782 Fuze

Exploded View

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Description

- The MOFA Post-launch Battery is a state-of-the-art reserve lithium oxyhalide power supply.
- It utilizes a moderate rate formulation of the lithium / thionyl chloride electrochemical couple.
- It can be stored in the dormant state for in excess of 20 years and then be activated by the conditions of ballistic launch.
- It uses a dashpot electrolyte reservoir system that enables it to survive drops without activation and degradation.
- It employs significant battery technologies:
    - Alliant's bipolar cell stack architecture,
    - Alliant's moderate rate thionyl chloride electrolyte,
    - ARL's dashpot reservoir technology.

MOFA Battery

Multi-Option Fuze for Artillery (MOFA)

Post-launch Battery

(Device No. G3158B2)

Performance

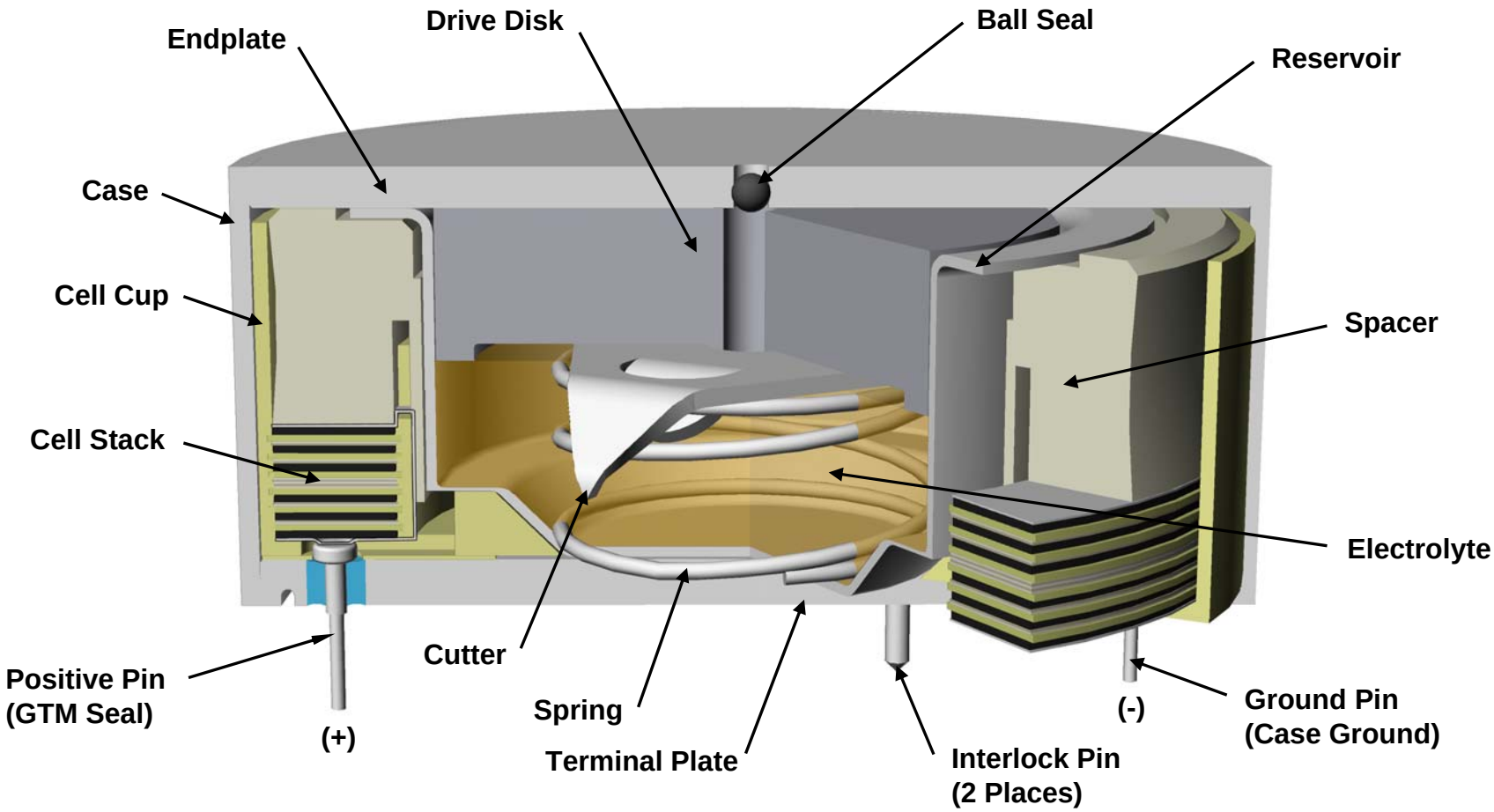
Voltage (V): 5.6 to 12.0
Current (mA): 325
Rated Capacity (mAh): 30
Activation Time (ms): < 100
Initiation Approach: Setback Initiated at > 3,000 G's & 3,600 RPM
Operating Temp. Range (°F): -45 to +145
Storage Temp. Range (°F): -60 to +160

Physical Characteristics

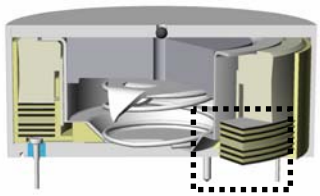
Chemistry: Moderate Power Li/$SOCl_2$
Size: 1.50" Dia. by 0.66" Length
Weight (g): 70

Environmental

MIL-STD-331 Environments
Acceleration (G): 30,000 max.
Spin (RPM): 30,000 max.

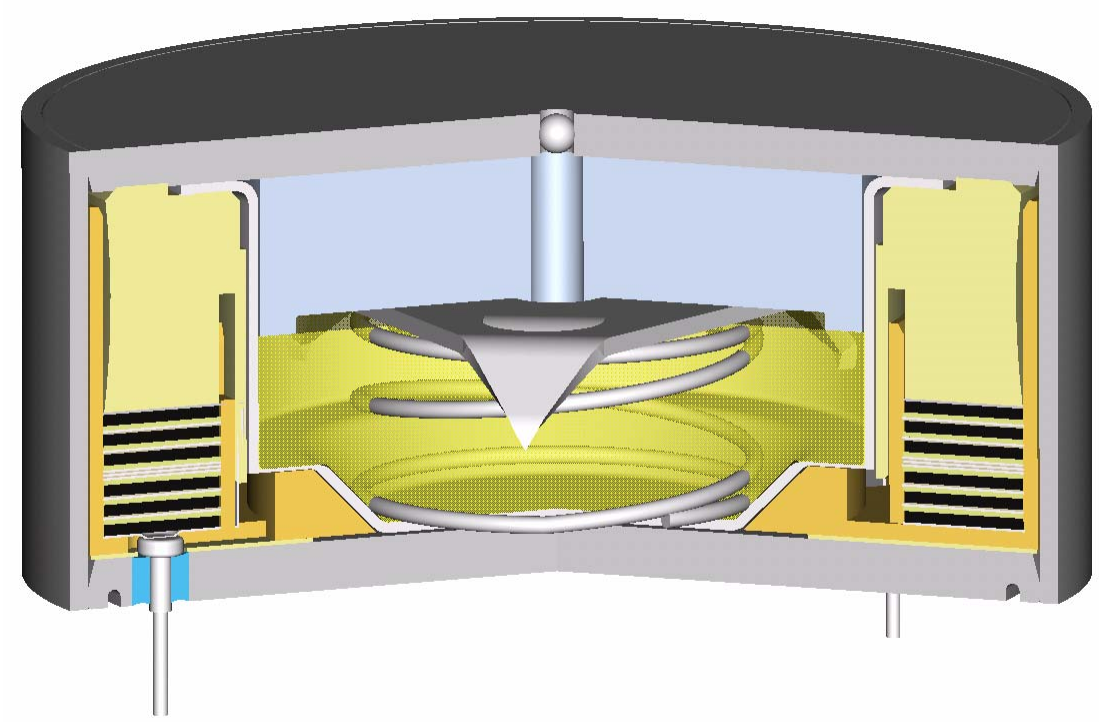


MOFA Post-launch Battery – Cross Sectional View

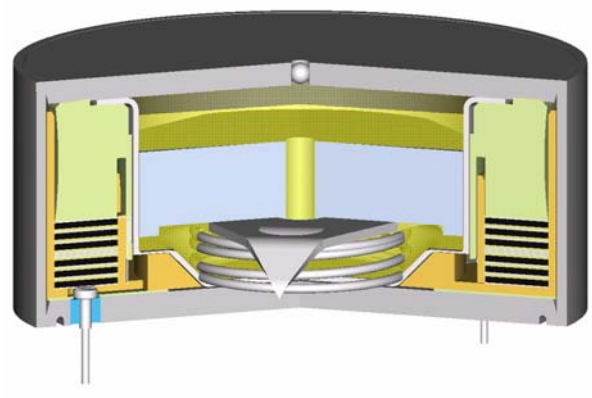


Area of Detail

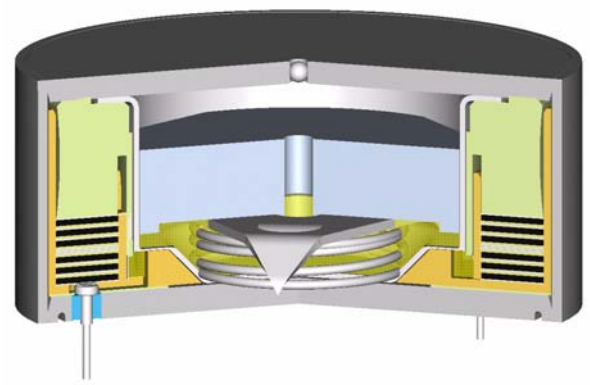
Quarter Cross Sectional View of MOFA Cell Stack Assembly



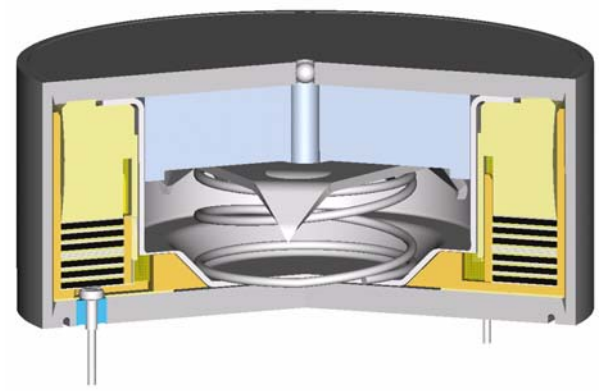
Battery in Dormant State



Setback Initiation



Spin Activation

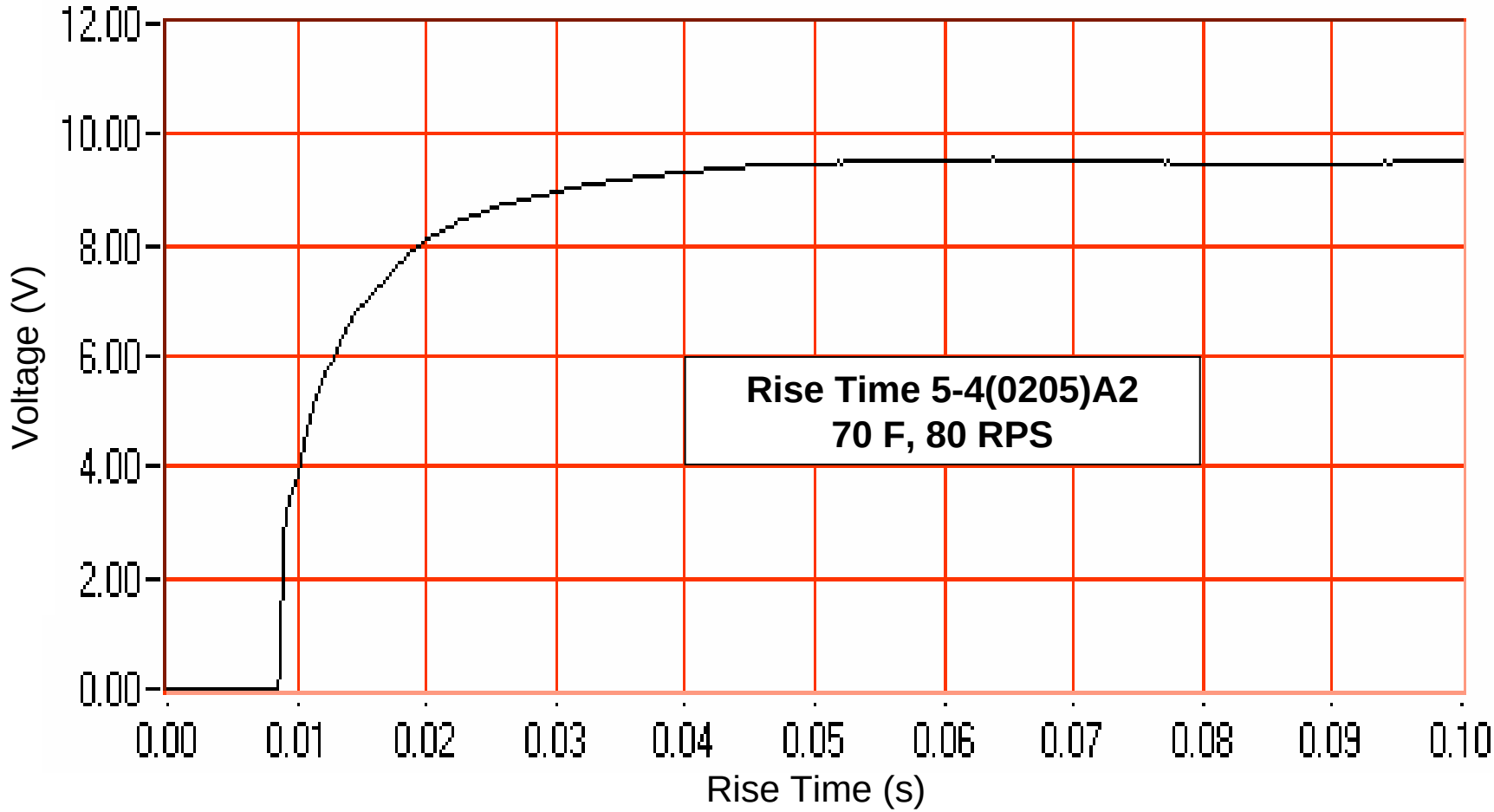


Fully Activated Battery

Battery Activation

Battery Performance

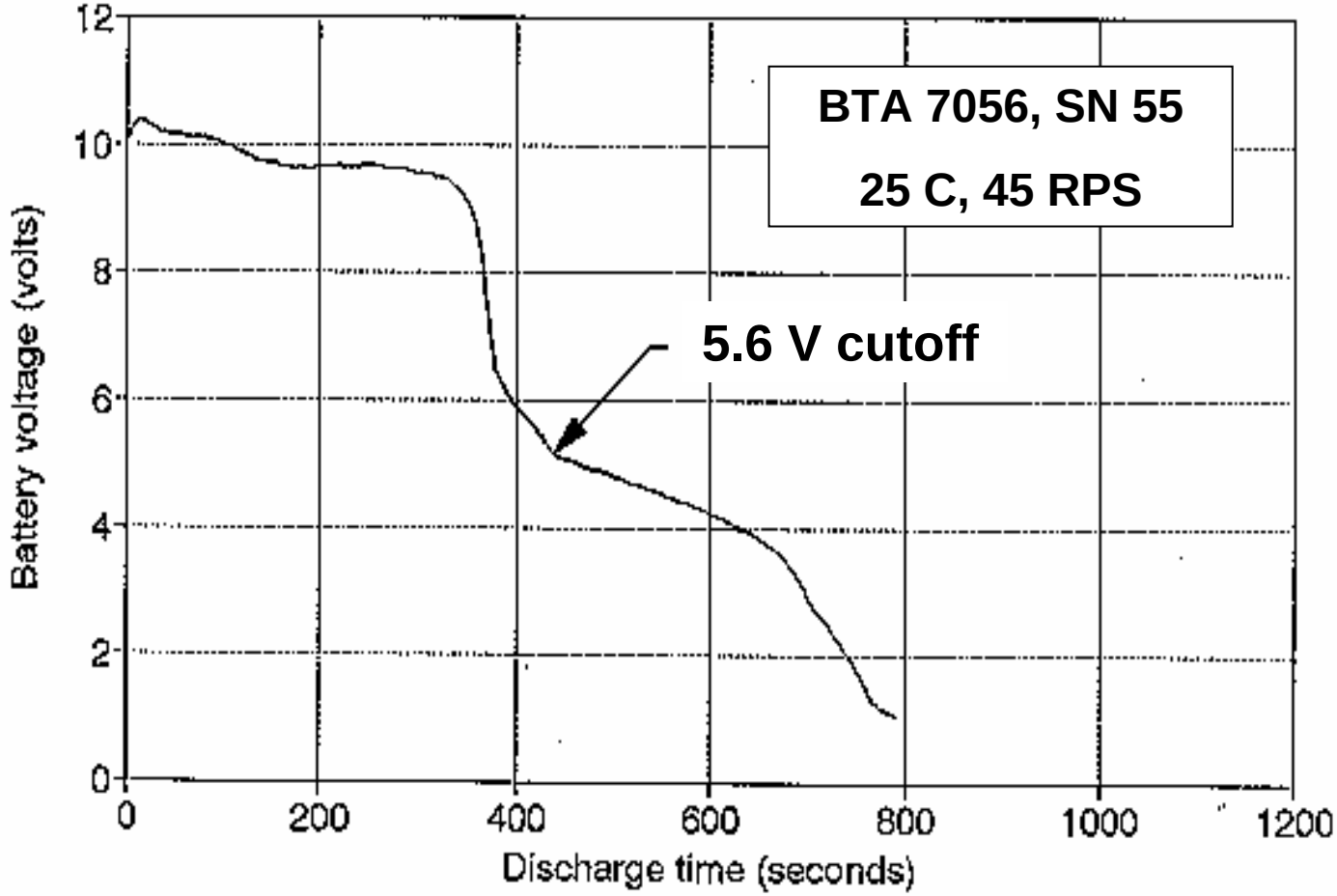
- **Battery performance has been characterized through a variety of tests. Thousands of batteries have been tested so far.**
- **Activation and risetime data was collected for the battery using a 155mm Howitzer with a soft catch and on-board recorder. Test conditions of temperature and launch acceleration were varied across the required ranges.**
  - **Average battery risetime to 5.6 volts is about 20 ms.**



Typical Battery Activation Performance

Battery Performance (Cont.)

- **Battery voltage, current capability, and life were measured under both static and dynamic conditions. Spin airguns were used to activate and discharge the batteries across the full temperature range under a variety of spin rates.**
  - **Open circuit voltage for the battery is 11.7 volts.**
  - **Under worst case operating conditions of -45°F and a load of 325 mA the battery discharges at 9.8 volts and is capable of runtimes of 300 s.**



Typical Voltage Profile

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Battery Performance (Cont.)

- **The battery structure was evaluated via extreme ballistics testing using a 57mm gun. Test rounds were fired vertically at 30,000 g's and recovered.**
  - **The results of these tests found the battery to be robust and capable of surviving the maximum launch acceleration without sustaining damage.**
- **Five foot drop testing of the battery in mockup fuzes was conducted in all five drop orientations per MIL-STD-331.**
  - **The battery was found to survive the drops without activating or suffering any other type of degradation.**

Modular, Extendable Design

- **The battery's architecture (both mechanical initiation and electrode structure) is tailorable to meet a variety of activation modalities and electrical performance requirements.**
- **Modular cell stacks can be internally connected in series to yield higher voltages or in parallel to yield higher current capability.**
- **The battery's capacity can also be tailored to meet different system requirements.**

Modular, Extendable Design

Cell Stack Architecture Modifications

- **Cell stacks can be reconfigured to provide a variety of power and energy outputs. A few performance examples are:**
  - **Over 30 volts at 150 mA.,**
  - **Over 18 volts at 250 mA.,**
  - **Over 10 volts at 350 mA., etc.**
- **High energy density permits the drop in replacement of some other electrochemical systems, I.e., form, fit, and function replacement.**

Modular, Extendable Design

Activation Mechanism Modifications

- **Incorporated M42 percussion primer for battery activation.**
  - **Enables battery to be used for "soft launch" environments.**
  - **Successfully incorporated modifications and demonstrated the required performance and reliability.**
- **Other variants are possible.**

Battery Device # G3161A1

Summary

- **The development effort was successful in designing a reserve, g-activated, primary battery which combines the benefits of the high energy density Li/$SOCl_2$ electrochemical couple with ARL's dash-pot electrolyte reservoir technology.**
- **This combination is well suited to artillery fuzing applications which require:**
  - **fast activation**
  - **relatively high power**
  - **long active life**
  - **cold temperature operation**

Acknowledgements

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