Munitions Batteries

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Hyatt Regency, Buffalo, NY

Lithium Battery Innovations
For Projectile Munitions

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Munitions Batteries

Agenda

• Applications
• Battery Characteristics
• Electrochemistries
• Challenges
• Innovations
• Performance Characterization
• Selected Cells
• Selected Batteries
• Summary

Li-Ion FTS Battery (Device No. G3203B1)
Lithium Battery Applications

Large Caliber Projectiles

Medium Caliber Projectiles

Barrier Munitions

Whether your application is on the Land, Sea, Air, or Space, EnerSys can provide the power.
1. Long Shelf Life
Lithium reserve batteries are unique in their ability to last for over 20 years prior to activation. This long shelf life is made possible by either storing the active materials separately until activation or by storing the active materials in a non-ionically conductive state until activation.

2. Temperature Range
Capable of operation across the full military temperature range (-65°F to +221°F/-54°C to +105°C).

3. Environmentally Hardened
Our lithium reserve batteries are optimized for operation in high acceleration environments (up to 100,000 g’s) and high spin rate (30,000 RPM), applications that ordinary batteries cannot survive.
Battery Characteristics

**Characteristics in Common**
- Self-contained
- Hermetic
- Reserve primary
- Lithium power sources
- Capable of being stored in excess of 20 years
- Activated on demand or by the conditions of deployment.
- Operation over the full military temperature range.

**Ambient Temperature Batteries**

Lithium / Oxyhalide Power Sources
- Achieve dormancy by physically separating the active components, i.e., the lithium foil anode and the thionyl chloride electrolyte.
- Cells and batteries can achieve activation within milliseconds and then provide power and deliver energy to support mission requirements.

**Thermal Batteries**

Lithium Alloy / Metal Disulfide Molten-Salt Power Sources
- Achieve dormancy by storing the electrodes in a non-ionically conductive state until deployed.
- Batteries can achieve activation within hundreds of milliseconds.

**Munitions Batteries**
Electrochemical Systems

Products Offered
- Lithium Thermal Batteries
- Lithium Ambient Temperature Batteries
- Lithium-Ion Rechargeable Batteries

Electrochemical Systems
- Lithium Silicon/Cobalt Disulfide (LiSi/CoS$_2$)
- Lithium Silicon/Iron Disulfide (LiSi/FeS$_2$)
- Lithium/Thionyl Chloride (Li/SOCl$_2$)
- Lithium/Sulfuryl Chloride (Li/SO$_2$Cl$_2$)
- Lithium/Sulfur Dioxide (Li/SO$_2$)
- Lithium/Vanadium Pentoxide (Li/V$_2$O$_5$)
- Lithium-Ion (various chemistries)

Automated Manufacturing
- Multiple automated manufacturing lines are used to produce Ambient Temperature Batteries and Thermal Batteries.
Activation Methods

- Batteries can be activated on demand or by the conditions of deployment, such as: ballistic launch, aircraft release, or canister dispense, etc. using one or more of the following methods:

<table>
<thead>
<tr>
<th>Method</th>
<th>Initiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Igniter</td>
<td>Electrical Pulse</td>
</tr>
<tr>
<td>Electric Primer</td>
<td>Electrical Pulse</td>
</tr>
<tr>
<td>Percussion Primer</td>
<td>Firing Pin, Lanyard</td>
</tr>
<tr>
<td>Stab Initiated</td>
<td>Squib, Thumb Screw</td>
</tr>
<tr>
<td>G-activation</td>
<td>Launch Acceleration, Target Impact</td>
</tr>
</tbody>
</table>

- Batteries can be activated within milliseconds to seconds.
## Munitions Batteries

### Challenges

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Potential Solution</th>
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<tbody>
<tr>
<td>Faster Initiation</td>
<td>Lower Viscosity Electrolytes</td>
</tr>
<tr>
<td>Improved Function Cold</td>
<td>Electrolytes with Greater Ionic Conductivities</td>
</tr>
<tr>
<td>Greater Power</td>
<td>Lower Cell Impedance</td>
</tr>
<tr>
<td>Greater Energy</td>
<td>Increased Active Material Content</td>
</tr>
</tbody>
</table>

**Activation Risetime**

**Cold Temp. Performance**

**Power Capability**

**Deliverable Capacity**
Innovations

Advanced Electrolytes for Improved Cold Temperature Operation

Lower Viscosity Electrolytes

Greater Ionic Conductivities

New electrolytes are stable for 20+ year storage! Enhanced cold temp Conductivity and Viscosity give excellent rise time and voltage performance.
Battery Configurations (Liquid Reserve Primary)

What’s the best configuration?

- **Long Mission Life High Energy**
  - Discrete Unit Cells
    - Cells consisting of one set of electrodes.

- **Moderate Power**
  - Bipolar Cells
    - Cells connected in series using bipolar elements.

- **High Power**
  - Hybrid Bipolar Cells
    - Cells with multiple internal parallel connections that are connected in series using bipolar elements.

Performance requirements may be met by selecting the battery configuration most suited to the application.
Advanced Power Source for Medium and Large Caliber Projectiles

G3207A1 - Cell
1S2P Internal Electrode Structure

G3207B1 - Battery
2S1P Internal Electrode Structure

Power Source Size
Ø0.450” Max X 0.395” Max Length
(Not including terminal pin)

Innovative design allows for parallel or series electrode configurations in same size format. Power source can be configured to meet customers power and energy needs.
The series configuration provided higher voltage but shorter runtime under identical loading at the worse-case cold temperature extreme.
The series configuration provided higher voltage but shorter runtime under identical loading at room temp ambient.
The series configuration provided higher voltage but shorter runtime under identical loading at the worse-case high temperature extreme.
Advanced Power Source for Next Gen Extended Range Projectiles

**Thermal Battery Innovations for Extended Runtime**

- High Quality Electrode Materials
- State-of-the-Art Electrochemistries
- Advanced Mechanical Designs
  - Designed for Ballistic Launch Survivability
  - Designed for Optimal Thermal Management
- State-of-the-Art Insulation Materials
- Automated Production
  - High Rate Production
  - Consistent Build Quality
  - Repeatable Performance

**G3220A1 - Battery**

Power Source Size

Ø1.50” Max  X 3.00” Max Length

(Not including terminal pins)

Extended range capability in efficient battery size.
Advances allow weapons to have longer flight times and engage targets at greater distances with improved accuracy.

EAS’s use of advanced materials, superior electrochemistry, and state-of-the-art design resulted in 2.5X runtime improvement at cold temperature extreme.
EAS's use of advanced materials, superior electrochemistry, and state-of-the-art design resulted in 2.0X runtime improvement at ambient temperature.
EAS’s use of advanced materials, superior electrochemistry, and state-of-the-art design resulted in a 1.8X runtime improvement at hot temperature extreme.
### Sub-munitions

<table>
<thead>
<tr>
<th>Device Number</th>
<th>Electrochemistry</th>
<th>Size (in)</th>
<th>Voltage (V)</th>
<th>Current (mA)</th>
<th>Activation Time(s)</th>
<th>Run Time (s)</th>
<th>Capacity (mAh)</th>
<th>Weight (gm)</th>
<th>Acceleration (G)</th>
<th>Spin (RPS)</th>
<th>Activation App.</th>
<th>Activation Acc. (G)</th>
<th>Applications</th>
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</thead>
<tbody>
<tr>
<td>G3168B1</td>
<td>Li/SO_2Cl_2</td>
<td>Φ.220 x .215</td>
<td>2.5 - 4.25</td>
<td>0.250</td>
<td>10 days</td>
<td>20 days</td>
<td>2,500</td>
<td>10,000</td>
<td>60.0</td>
<td>200</td>
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<td>N/A</td>
<td>Self-Destruct</td>
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<td></td>
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<td></td>
<td>2.0 - 3.8</td>
<td>0.025</td>
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<td>Fuzing</td>
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<td>0.250</td>
<td>&gt;30</td>
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### 30 mm

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<th>Capacity (mAh)</th>
<th>Weight (gm)</th>
<th>Acceleration (G)</th>
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<tr>
<td>G3198B1</td>
<td>Li/ClO_2</td>
<td>Φ.275 x .325</td>
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<td>0.050</td>
<td>30</td>
<td>10 days</td>
<td>30</td>
<td>50</td>
<td>0.5</td>
<td>200</td>
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<td>N/A</td>
<td>Low</td>
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### 40 mm

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<th>Run Time (s)</th>
<th>Capacity (mAh)</th>
<th>Weight (gm)</th>
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<th>Activation App.</th>
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<th>Applications</th>
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<td>G3165D1</td>
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<th>Capacity (mAh)</th>
<th>Weight (gm)</th>
<th>Acceleration (G)</th>
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<th>Activation App.</th>
<th>Activation Acc. (G)</th>
<th>Applications</th>
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<tbody>
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<td>G3207A1</td>
<td>Li/ClO_2</td>
<td>Φ.350 x .435</td>
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<td>0.050</td>
<td>30</td>
<td>10 days</td>
<td>30</td>
<td>50</td>
<td>0.5</td>
<td>200</td>
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<td>N/A</td>
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<td>0.050</td>
<td>&gt;30</td>
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<td>0.250</td>
<td>5.2</td>
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<th>Spin (RPS)</th>
<th>Activation App.</th>
<th>Activation Acc. (G)</th>
<th>Applications</th>
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</thead>
<tbody>
<tr>
<td>G2666B1</td>
<td>Li/ClO_2</td>
<td>Φ.500 x .840</td>
<td>2.5 - 3.6</td>
<td>0.6</td>
<td>&gt;30</td>
<td>10 days</td>
<td>50</td>
<td>500</td>
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<td>280</td>
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<td>N/A</td>
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### Munitions

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<th>Run Time (s)</th>
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<th>Activation App.</th>
<th>Activation Acc. (G)</th>
<th>Applications</th>
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<tbody>
<tr>
<td>G3147A1</td>
<td>Li/ClO_2</td>
<td>Φ.500 x .840</td>
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<td>&gt;30</td>
<td>10 days</td>
<td>50</td>
<td>500</td>
<td>0.8</td>
<td>280</td>
<td>N/A</td>
<td>N/A</td>
<td>Artillery</td>
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### Artillery

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<thead>
<tr>
<th>Device Number</th>
<th>Electrochemistry</th>
<th>Size (in)</th>
<th>Voltage (V)</th>
<th>Current (mA)</th>
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<th>Run Time (s)</th>
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<th>Weight (gm)</th>
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<td>3.4</td>
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</tbody>
</table>

**EnerSys offers a wide range of state-of-the-art Reserve Lithium/Oxyhalide Cells for medium and large caliber projectile fuzing.**
### Selected Batteries

<table>
<thead>
<tr>
<th>Device Number</th>
<th>Electrochemistry</th>
<th>Size (in)</th>
<th>Voltage (V)</th>
<th>Current (mA)</th>
<th>Activation Time(s)</th>
<th>Run Time (s)</th>
<th>Capacity (mAh)</th>
<th>Weight (gm)</th>
<th>Acceleration (G)</th>
<th>Spin (RPS)</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>G3207B1</td>
<td>Li/SOCl₂</td>
<td>0.450 x 0.395</td>
<td>3.0 – 7.6</td>
<td>50</td>
<td>0.050</td>
<td>25</td>
<td>0.6</td>
<td>2.0</td>
<td>25,000.</td>
<td>300</td>
<td>40 mm</td>
</tr>
<tr>
<td>G3153A2</td>
<td>Li/SOCl₂</td>
<td>1.510 x 1.255</td>
<td>20.0 – 40.0</td>
<td>750</td>
<td>0.025</td>
<td>10</td>
<td>20.0</td>
<td>110.0</td>
<td>55,000. Low</td>
<td>Low</td>
<td>Stab/Primer</td>
</tr>
<tr>
<td>G3153B1</td>
<td>Li/SOCl₂</td>
<td>0.880 x 1.280</td>
<td>25.0 – 40.0</td>
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<td>0.025</td>
<td>20</td>
<td>8.0</td>
<td>51.2</td>
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<td>57.0</td>
<td>Low Setback</td>
</tr>
<tr>
<td>G3158B3</td>
<td>Li/SOCl₂</td>
<td>1.500 x 0.670</td>
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<td>200</td>
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<td>200</td>
<td>35</td>
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<td>12,600. Low Electric Fuzing, Projectiles, Bombs</td>
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<td>Li/SOCl₂</td>
<td>1.500 x 0.670</td>
<td>5.6 – 12.0</td>
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<td>57.0</td>
<td>30,000. Low</td>
<td>12,600. Low Electric Fuzing, Projectiles, Bombs</td>
<td></td>
</tr>
</tbody>
</table>

*EnerSys offers a wide range of state-of-the-art Reserve Lithium/Oxyhalide Batteries for medium and large caliber projectile fuzing.*

EAS

Ambient Temperature Batteries

Selected Batteries

40 mm

120 mm

120 mm

155 mm

Air Delivered

Projectiles

G3207B1

G3153A2

G3153B1

G3158B3

G3161A1

G3177A1

Li/SOCl₂

Li/SOCl₂

Li/SOCl₂

Li/SOCl₂

Li/SOCl₂

1.500 x 0.670

1.500 x 0.670

1.500 x 0.670

1.500 x 0.670

1.500 x 0.670

5.6 – 12.0

5.6 – 12.0

5.6 – 12.0

5.6 – 12.0

5.6 – 12.0

350

350

350

350

350

0.050

0.025

0.025

0.100

0.100

25

10

20

20

20

300

1,000.

1,000.

1,000.

1,500.

1,500.

25,000.

55,000.

55,000.

30,000.

30,000.

120 mm Tank Munitions, ES&A Fuzing

120 mm Tank Munitions, ES&A Fuzing

155 mm & 105 mm Artillery Fuzing

Electronic Fuzing, Projectiles, Bombs

N/A

N/A

N/A

N/A

N/A

Medium and Large Caliber Projectile Fuzing

ES&A Fuzing

ES&A Fuzing

ES&A Fuzing

ES&A Fuzing

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Stab/Primer

N/A

N/A

N/A

N/A
EnerSys offers machine produced Reserve Batteries for high volume applications such as medium and large caliber projectile fuzing.
Summary

- Several innovations were presented in the areas of electrochemistry and battery design that provide enhanced performance and capability for next generation electronic fuzing.
- Selected cells and batteries offering enhanced performance were discussed.
- EnerSys is a $3.0 billion/year American company with munitions battery manufacturing facilities located in Horsham, Pennsylvania and Tampa, Florida.
- EAS has all of the physical assets and facilities required to: design, develop, manufacture, test, and analyze lithium batteries.
- Thank you for your attention.

*EnerSys provides high energy density “lithium/oxyhalide batteries” and high power density “thermal batteries” as well as secondary “lithium ion batteries”.*