Center for Research in Extreme Batteries (CREB)
The Future of Munitions Batteries Workshop

Advanced Munitions Batteries
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Agenda

• Munitions Batteries Overview
  – Thermal Batteries
  – Ambient Temperature Batteries
  – Secondary Batteries

• Future Direction
EnerSys Advanced Systems is the leading producer of lithium reserve batteries in the U.S. We have provided state-of-the-art batteries to the U.S. Army for over 50 years and have delivered over 30 million primary batteries to the DoD and allied governments.

EnerSys (EAS’ parent company) is a $2.5 billion/year, publically traded, American company. EnerSys operates 32 manufacturing facilities around the world. EAS is comprised of 6 of those facilities, all dedicated to lithium batteries, and 2 of which (located in the US) are focused on munitions batteries.

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

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

Electrochemical Systems
- Lithium Silicon/Cobalt Disulfide (LiSi/CoS₂)
- Lithium Silicon/Iron Disulfide (LiSi/FeS₂)
- Lithium/Thionyl Chloride (Li/SOCl₂)
- Lithium/Sulfuryl Chloride (Li/SO₂Cl₂)
- Lithium/Sulfur Dioxide (Li/SO₂)
- Lithium/Vanadium Pentoxide (Li/V₂O₅)
- Lithium-Ion (various chemistries)

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

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.

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

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.

Lithium reserve batteries for smart weapons and electronic fuzing applications.
Munitions Batteries Overview

Automated Manufacturing

• EnerSys automates manufacturing where it makes sense.
  • High rate and high volume production
  • Ambient Temperature Batteries
  • Thermal Batteries
• Semi-automated production
  • Machine assisted manufacturing
• Fully automated production
  • Machine produced electrodes and assemblies
  • Human support to equipment minimized
• Benefits of automation
  • Improved battery performance
  • Improved repeatability & consistency, i.e., tighter perf. groupings
  • Zero defects/escapes
  • Higher manufacturing throughput
  • Lower cost – *last but not least!*

*EnerSys automated battery manufacturing offers many benefits.*
The Future of Munitions Batteries

Features:
- Two Facilities: 112,500 ft².
- 18,000 ft² of Humidity Controlled Dry Rooms.
- Extensive Computer Modeling & Analysis Capabilities.
  - Electrochemical, Thermal, & Structural
- Lithium Battery Development, Manufacturing & Testing
  - Lithium Oxyhalide Primary Reserve Batteries
  - Lithium - Metal Disulfide Thermal Batteries
    - LiSi / FeS₂ and LiSi / CoS₂
    - Wide Range of Sizes, Voltages & Power Levels
  - Full Range of Non-Destructive & Destructive Test Systems (static & dynamic environments)
    - Digital X-Ray, Loads to 96 kW, High-g Shock, Vibration, Acceleration, Temperature / Humidity
- Power Wide Range of Tactical, Strategic Defense & Civil Space Systems
- Quality Management Systems Certified:
  - ISO 9001:2008
  - AS9100C

Munitions Batteries Facilities

EAS has all of the physical assets and facilities required to: design, develop, manufacture, test, and analyze lithium batteries.
The Future of Munitions Batteries

Ballistic Missile Defense

EnerSys Powers Multiple Mid-Course & Terminal Phase Systems
The Future of Munitions Batteries

Examples of Tactical & Strategic Defense Applications
Selected Thermal Batteries

*Thermal Batteries can be Activated Electrically or by the Conditions of Ballistic Launch.*
**Performance**
- Voltage (V): 24 to 35
- Current (mA): 800, 1.8A 2s Pulse
- Rated Capacity (mAh): 730
- Activation Time (ms): < 1000
- Initiation Approach: Electric Igniter
- Operating Temp. Range (°F): -58° to +178°
- Storage Temp. Range (°F): -65° to +221°

**Physical Characteristics**
- Chemistry: LiSi/FeS\(_2\)
- Size: 3.00” Dia. by 3.50” Length
- Weight (lbs): 3 Max
- 11 Pin Terminal Plate
- 3 Redundant Voltage Connections
- Robust Bracket Design

**Environmental**
- MIL-STD-331 Environments
- NAVSEA 9310 Lithium Battery Safety
- RCC319-10 Battery Requirements

The G3206A1 LiSi/FeS\(_2\) Thermal Battery provides an active life greater than 35 minutes across the full temperature range (-58°F to +178°F).
The EnerSys G3190B2 Lithium Silicon/Iron Disulfide (LiSi/FeS₂) Thermal Battery powers the DSU-33 Proximity Sensor used on the Joint Direct Attack Munition (JDAM) bombs.

**Performance**
- Voltage (V): 22 to 32.0
- Current (mA): 700
- Rated Capacity (mAh): 39
- Activation Time (ms): < 500
- Initiation Approach: Electric Igniter
- Operating Temp. Range (°F): -65 to +221
- Storage Temp. Range (°F): -65 to +221

**Physical Characteristics**
- Chemistry: LiSi/FeS₂
- Size: 1.50” Dia. by 2.38” Length
- Weight (g): 250

**Environmental**
- MIL-STD-331 Environments
- NAVSEA 9310 Lithium Battery Safety

F-15 drops JDAM-equipped bombs in Afghanistan.
(U.S. Air Force photo by Staff Sgt. Michael B. Keller)
EnerSys offers a wide range of state-of-the-art Reserve Lithium/Oxyhalide Cells for medium and large caliber projectile fuzing.
Performance
Voltage (V): 2.5 to 3.6
Current (mA): 0.5
Rated Capacity (mAh): 280
Activation Time (ms): < 800
Initiation Approach: Stab Initiation
Operating Temp. Range (F): -25° to +160°
Storage Temp. Range (F): -60° to +160°

Physical Characteristics
Chemistry: Li/SOCl₂
Size: 0.50” Diameter by 0.84” Length
Weight (g): 6.2

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

The G3147A1 Li/SOCl₂ Artillery Fuze Cell offers high energy in a robust design capable of withstanding the extreme conditions of ballistic launch.
Ambient Temperature Batteries

Performance
- Voltage (V): 5.0 to 7.5
- Current (mA): 36
- Rated Capacity (mAh): 350
- Activation Time (s): 2.0
- Initiation Approach: Dual Electric Primers
- Operating Temp. Range (F): -45° to +110°
- Storage Temp. Range (F): -65° to +150°

Physical Characteristics
- Chemistry: Li/SOCl₂
- Size: 1.516” Width by 2.40” Length
- Weight (g): 80

Environmental
- MIL-STD-331 Environments
- Acceleration (G): 12,600 max.

The G3177A1 Li/SOCl₂ Data Hold Battery utilizes a 2S2P configuration to support essential data hold functions in guided projectiles.
Performance
- Voltage (V): 5.6 to 12.0
- Current (mA): 350
- Rated Capacity (mAh): 35
- Activation Time (s): ≤ 100
- Initiation Approach: Setback Initiation
- Operating Temp. Range (F): -45⁰ to +145⁰
- Storage Temp. Range (F): -60⁰ to +160⁰

Physical Characteristics
- Chemistry: Li/SOCl₂
- Size: 1.50” Diameter by 0.67” Length
- Weight (g): 71

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

The G3158B3 Li/SOCl₂ Artillery Fuze Battery can sit in the dormant state for in excess of 20 years and then be activated by the conditions of ballistic launch.
The G3203B1 Flight Termination Systems (FTS) Battery uses an 8S1P configuration of standard lithium-ion 18650 cells.
**Secondary Batteries**

**Performance**

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<th>2, FTS</th>
<th>3, FTS</th>
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<td>Current (A):</td>
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<tr>
<td>Rated Capacity:</td>
<td>0.813 Ah</td>
<td>0.325 Ah</td>
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<td>Op. Temp. (F):</td>
<td>20 to 110</td>
<td>10 to 120</td>
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<tr>
<td>Stor. Temp. (F):</td>
<td>20 to 85</td>
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**Physical Characteristics**

- **Chemistry:** Lithium Ion Polymer
- **Size:** 4.150” Diameter X 4.00” Length
- **Weight (Lb):** 8.4

**Environmental**

Ballistic Conditions of Gun Launch.

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The G3174A3 Instrumentation Battery provides a telemetry section and two fully redundant flight termination systems sections.
Future Direction

• Future Enhancements:

  Thermal Batteries
    » Longer Mission Life
    » Higher Deliverable Energy
    » Smaller Size

  Ambient Temperature Batteries
    » Faster Activation at Cold Temperature
    » Higher Power at Cold

  Secondary Batteries
    » Improved Performance at Cold Temperature

Thank You for Your Attention!