59th Annual NDIA Fuze Conference

Selecting and Specifying Lithium Batteries for Advanced Fuzing Systems

Charleston Marriott, Charleston, SC

May 3-5, 2016

Paul F. Schisselbauer
EnerSys Advanced Systems,
Power Sources Center
104 Rock Road
Horsham, PA 19044

Tel: (215) 773-5416
Fax: (215) 773-5444
E-mail: Paul.Schisselbauer@enersys.com

Monica V. Stoka
EnerSys Advanced Systems,
Power Sources Center
104 Rock Road
Horsham, PA 19044

Tel: (215) 773-5423
Fax: (215) 773-5499
E-mail: Monica.Stoka@enersys.com

Agenda

- General Selection Criteria
  - Specifying Requirements
  - Environmental Considerations
- Electrochemistry
  - Suitability
  - Power Versus Energy
- Battery Configurations
  - Configurations
  - Benefits & Limitations
- Common Battery Types
  - Thermal Batteries
  - Ambient Temperature Batteries
  - Secondary/Rechargeable Batteries
- Summary

General Selection Criteria

- Specifying Requirements
  - Voltage
  - Current
  - Activation Time
  - Operational Life
  - Capacity
  - Temperature Range
  - Size
  - Weight
  - Polarity

F-15 drops JDAM-equipped bombs in Afghanistan.
(U.S. Air Force photo by Staff Sgt. Michael B. Keller)

LiSi/FeS_2 Thermal Battery
(Device No. G3190B2)

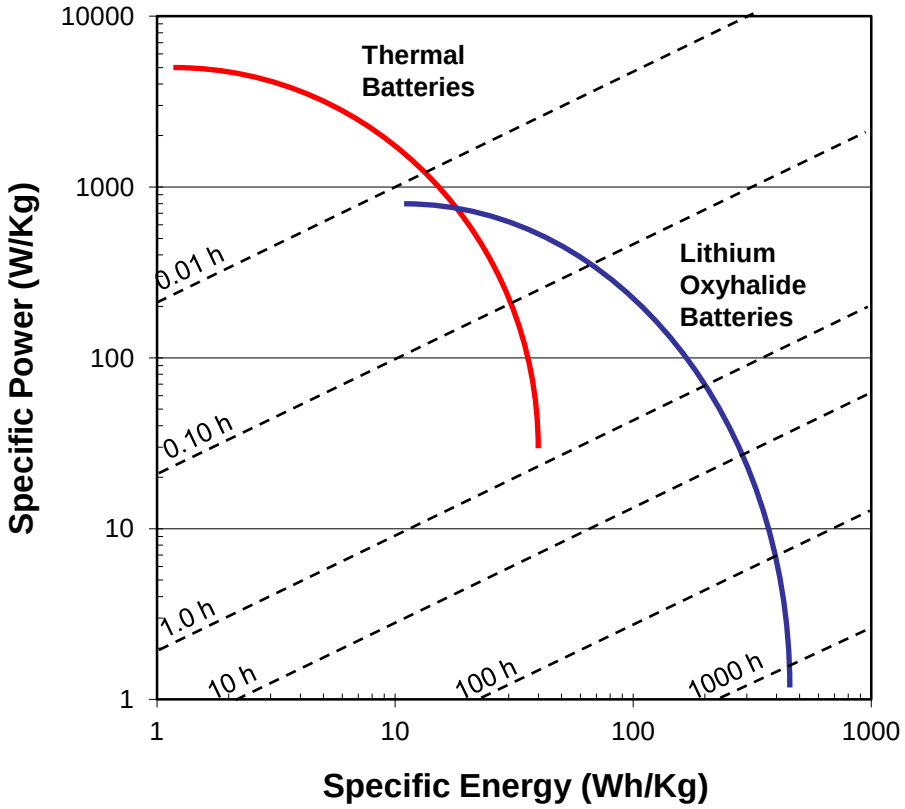
General Selection Criteria

- Environmental Considerations
  - Launch Acceleration
  - Shock
  - Vibration
  - Spin
  - Temperature Range

LiSi/FeS_2 Thermal Battery
(Device No. G3200A1)

Artillery Fuzing
155 mm Projectile

Electrochemistry



Ragone Plot Comparing Thermal Batteries to Lithium Oxyhalide Batteries.

(Approximate data - plot for illustration purposes only)

- **Certain battery systems are ideally suited to military applications.**
  - **Cold Operating Temp.**
  - **Long Shelf Life.**
- **Lithium Oxyhalide Batteries are best suited to applications that require extended life.**
  - **Lithium/Thionyl Chloride**
  - **Lithium/Sulfuryl Chloride**
  - **Lithium/Sulfur Dioxide**
- **Thermal Batteries are best suited to applications that require high power.**
  - **Lithium Silicon/Iron Disulfide**
  - **Lithium Silicon/Cobalt Disulfide**

Battery Configurations

Active Primary

- Ready for discharge

Reserve Primary

- Can be activated on demand or by the conditions of deployment using one or more of the following methods:

Activation Method	Initiated By
Electric primer	Electrical pulse
Percussion primer	Firing pin or lanyard
Stab initiated	Squib or thumb screw
G-activation	Launch acceleration or target impact

- Batteries can be activated within milliseconds to seconds.

Secondary

- Rechargeable batteries with, and without, Battery Management Systems (BMS)

Benefits & Limitations

Battery Type	Pros	Cons
Active Primary Lithium	• Immediate power & energy. • Operating temp. range.	• Environmental robustness. • Limited shelf life.
Reserve Primary Thermal Batteries Liquid Reserve	• 20 year shelf life. • Operating temp. range. • Environmental robustness.	• Activation rise time. (ms to sec rise times)
Secondary Lithium Ion	• Immediate power & energy. • High cycle life.	• Environmental robustness. • Operating temp. range. • Limited shelf life.

Preferred technologies for Advanced Fuzing & Weapon Systems

Common Battery Types

AC130 Spectre - 105 mm Projectile

- Thermal Batteries
- Ambient Temperature Batteries
- Secondary/Rechargeable Batteries

LiSi/FeS_2 Thermal Battery
(Device No. G3208A1)

Thermal Batteries

$LiSi/FeS_2$ | $LiSi/CoS_2$

Lithium Thermal Batteries

- Self-contained, hermetic, electrochemical power sources.
- Capable of being stored in excess of 20 years.
- Achieve dormancy by utilizing electrolytes which require elevated temperature to become ionically conductive.
- Provide high current density for high power applications.
- Highly reliable.

Guided Mortar

Key Design Drivers – Mortar Applications

$LiSi/FeS_2$ Thermal Battery
(Device No. G3202A1)

Performance

Voltage (V): 11 to 24
Power (W): 11
Rated Capacity (mAh): 41
Activation Time (ms): < 500
Initiation Approach: Electric Igniter

Active Life (s): > 65.5
Operating Temp. Range (°F): -25º to +145º
Storage Temp. Range (°F): -50º to +160º

Physical Characteristics

Chemistry: $LiSi/FeS_2$
Size: 1.000" Dia. by 1.436" Length
Weight (g): 50

Environmental

MIL-STD-331 Environments
MIL-STD-810 Environments

The G3202A1 Lithium Silicon/Iron Disulfide Thermal Battery is designed to meet the extreme temperature and performance requirements of mortar applications.

High-speed Anti-Radiation Missile (HARM)

LiSi/FeS_2 FTS Thermal Battery
(Device No. G3206A1)

Key Design Drivers – FTS Applications

Performance

Voltage (V): 24 to 35
Rated Capacity (mAh): 730
Activation Time (ms): < 1000
Initiation Approach: Electric Igniter
Operating Temp. Range (°F): -58º to +178º
Storage Temp. Range (°F): -65º to +221º

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 ºF to +178 ºF).

Ambient Temperature Batteries

Active Primary Batteries

- Self-contained, hermetic, electrochemical power sources.
- Capable of being stored in excess of 5 years.
- Highly reliable.
- Minimal thermal management issues.
- Provide high energy density for extended mission times.
- Cost effective in high volume production.

Ambient Temperature Batteries

$Li/SOCl_2$ | Li/SO_2Cl_2 | Li/V_2O_5

Reserve Primary Batteries

- Self-contained, hermetic, electrochemical power sources.
- Capable of being stored in excess of 20 years.
- Achieve dormancy by physically separating the active components, i.e., the lithium foil anode and the electrolyte (catholyte).
- Provide high energy density for extended mission times.
- Highly reliable.
- Minimal thermal management issues.
- Cost effective in production.

G3168B1 Cell
Φ.220 x .215

G3201A1 Cell
Φ.275 x .325

G3198B1 Cell
Φ.319 x .359

G3165D1 Cell
Φ.350 x .435

G3207A1 Cell
Φ.450 x .395”

G2666B1
Φ.510 x .840

G3147A1 Cell
Φ.500 x .840

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

EnerSys. Power/Full Solutions™

M767 Artillery Fuze, 155 mm & 105 mm Projectiles

Key Design Drivers – Fuzing Applications

Artillery Fuze Battery
(Device No. G3147A1)

Performance

- **Voltage (V): 2.5 to 3.6**
- **Current (mA): 0.5**
- **Rated Capacity (mAh): 280**
- **Activation Time (s): < 800**
- **Initiation Approach: Stab Initiation**
- **Operating Temp. Range (F): -25º to +160º**
- **Storage Temp. Range (F): -60º to +160º**

Physical Characteristics

- **Chemistry: Li/$SOCl_2$**
- **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/$SOCl_2$ Artillery Fuze Cell offers high energy in a robust design capable of withstanding the extreme conditions of ballistic launch.

Extended Range Guided Munition (ERGM) 5" Projectile

Key Design Drivers – Projectile Applications

Data Hold Battery
(Device No. G3177A1)

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): -45º to +110º
Storage Temp. Range (F): -65º to +150º

Physical Characteristics

Chemistry: Li/$SOCl_2$
Size: 1.516" Width by 2.40" Length
Weight (g): 80

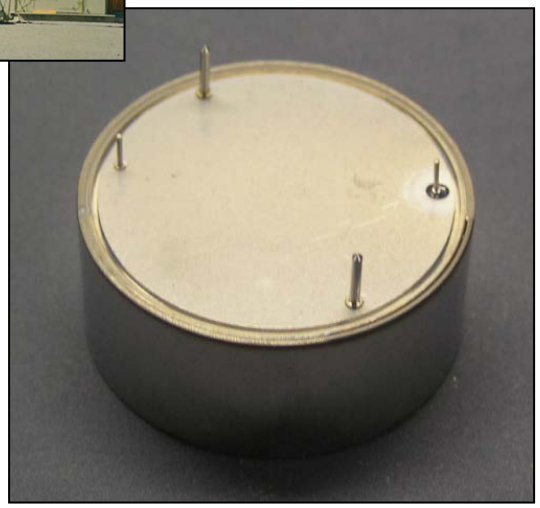
Environmental

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

The G3177A1 Li/$SOCl_2$ Data Hold Battery utilizes a 2S2P configuration to support essential data hold functions in guided projectiles.

Multi-Option Fuze for Artillery (MOFA) 155 mm & 105 mm Projectiles

Key Design Drivers – Artillery Applications



Artillery Fuze Battery
(Device No. G3158B3)

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): -45º to +145º
Storage Temp. Range (F): -60º to +160º

Physical Characteristics

Chemistry: Li/$SOCl_2$
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/$SOCl_2$ 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.

Secondary (Rechargeable) Batteries

- Lithium Ion & Lithium Ion Polymer Batteries
  - Robust battery designs for demanding environments.
  - High open circuit voltage.
  - No memory effect.
  - Low self-discharge.

Joint Air-to-Surface Standoff Missile (JASSM) Cruise Missile

Li-Ion FTS Battery
(Device No. G3203B1)

Key Design Drivers – FTS Applications – Li Ion

Performance

Voltage (V): 24 to 33.6
Current (A): 5 Discharge
1.0 Charge
Rated Capacity (Ah): 2.8 at 77^{0}F (25 ^{0}C)
Internal Heater: Yes
Operating Temp. Range (F):
Charge: 32^0 to +113^0
Discharge: -4^0 to +160^0
Storage Temp. Range (F): <95^0

Physical Characteristics

Chemistry: Li-Ion
Size: 6.26” x 3.56” x 1.34”
Weight (lb.): 2.05

Environmental

RCC319-10 FTS Battery Requirements
NAVSEA 9310 Lithium Battery Safety

The G3203B1 Flight Termination Systems (FTS) Battery uses an 8S1P configuration of standard lithium-ion 18650 cells

Multiple-band Avionics Radio Suite (MARS)

Li-Ion Communications Battery

Key Design Drivers – Communications Applications

Performance

Voltage (V): 6.0 to 10.8
Current (A): 0.03 Discharge
0.66 Charge
Rated Capacity (Ah): 1.3 C/5 at 77^{0}F (25^{0}C)
Operating Temp. Range (F): -40^0 to 160^0
Storage Temp. Range (F): -40^0 to 160^0

Physical Characteristics

Chemistry: Li-Ion
Size: 2.80” x 2.20” x 0.76”
Weight (oz.): 4.5 Nom.

Environmental

Altitude: 55,000 ft.

The Communications Battery uses an 3S1P configuration of standard lithium-ion 18650 cells

EnerSys Power/Full Solutions™

Summary

- Several battery types/configurations are typically used in advanced fuzing and weapon systems.
- Applications engineers can help in determining:
  - Requirements to specify
  - Suitability of the various battery chemistries for a particular application.

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

Thank you for your attention!