Novel Piezoelectric-Based Energy-Harvesting Power Sources for Gun-Fired Munitions

J. Rastegar, R. Murray, C. Pereira* and H-L., Nguyen*

Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706
Tel. (631) 665-4008

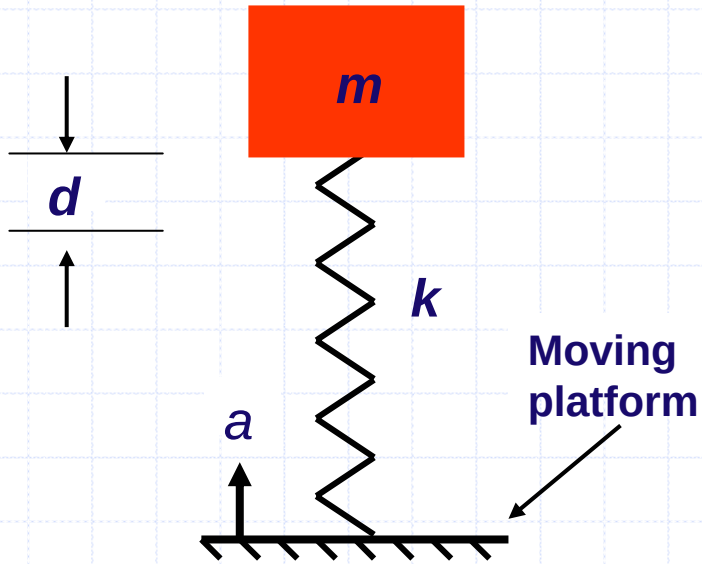
U. S. Army (ARDEC)
Picatinny Arsenal
New Jersey 07876

Sources of Energy for Power Generation Onboard Munitions

- Firing acceleration.
- Drag induced vibration.
- Spinning during the flight.
- Flow induced heating of leading surfaces during supersonic flight.
- Stored mechanical (potential) energy.
- Stored chemical energy.

Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

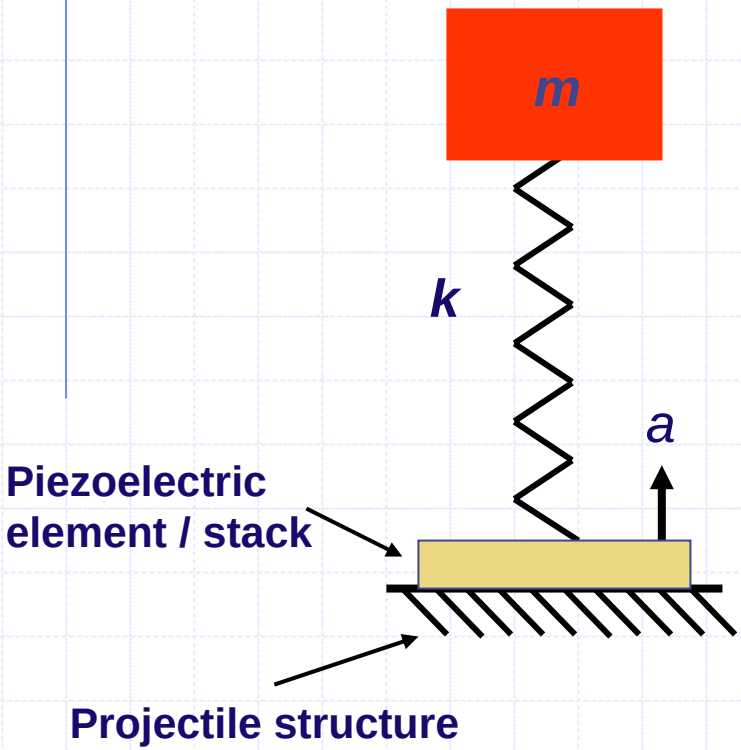
Electric Power Generation From Firing Acceleration – Basic Concept



- Firing acceleration *a* displaces mass *m* a distance *d.*
- Potential energy ½ *k* d^2 is stored in the spring *k*.
- Energy is then harvested from the vibrating mass-spring system using certain mechanical to electrical generator system.

Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

Piezoelectric-Based Energy Harvesting Power Sources for Gun-Fired Munitions

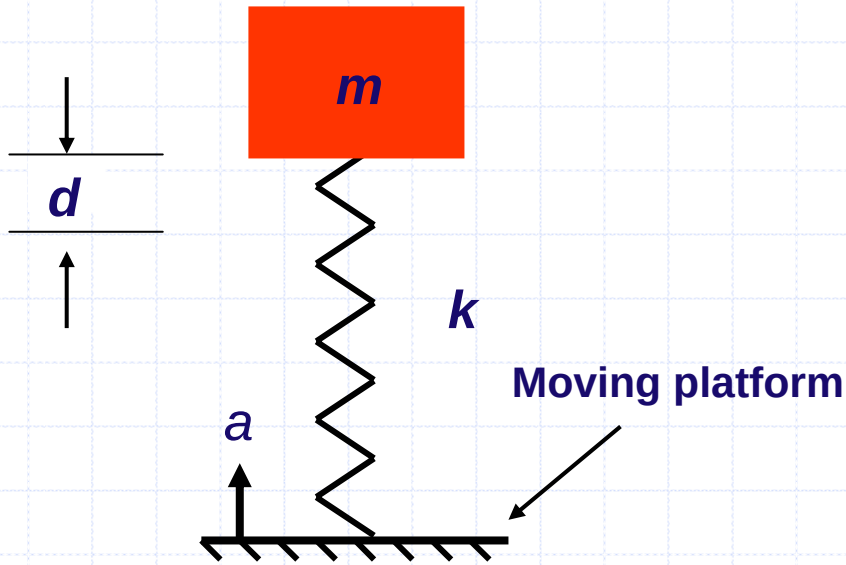


Design Challenges:

- Protect the piezoelectric elements.
- Stops to limit spring deflection.
- Minimize mass-spring side deflection.
- *k* and *m* selected to match required power and time history of power consumption.

Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

Example:



$F = ma = kd$

$P_E = ½\ k\ d^2 = ½\ m\ a\ d$

For *a* = 20,000 g, *m* = 0.1 *kg*, *d* = *0.025 m* (1 inch):

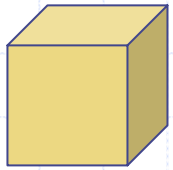
$P_E = 245$ *N-m (Joules)*

With energy conversion efficiency of 50 %, and *t= 2 sec.* of continuous use, the power generated becomes:

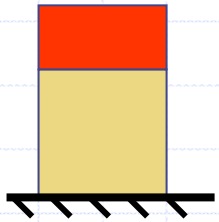
W = 60 watts

Basic Power Generation Concept

Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706



0.5 inch cube
Piezo



M = 55 gr

a=20,000 G

σ=10,000 psi

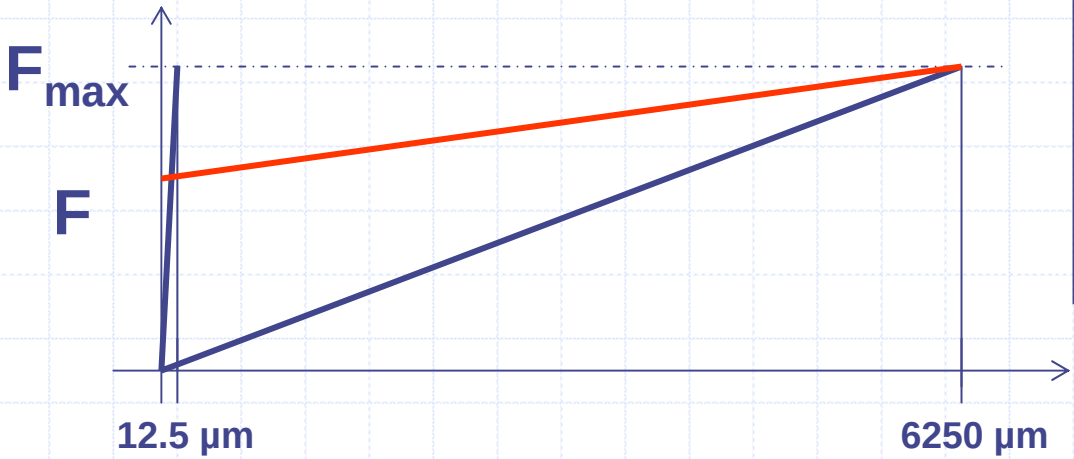
F = 2500 lbs

$\Delta L = F\,L / A\,E$ = maximum possible change in the height of piezo

(2500 lbs)(0.5 in)/(0.25 in^2)(10X10^{10} psi)= 0.0005 in = 12.5 X 10^{-10} m

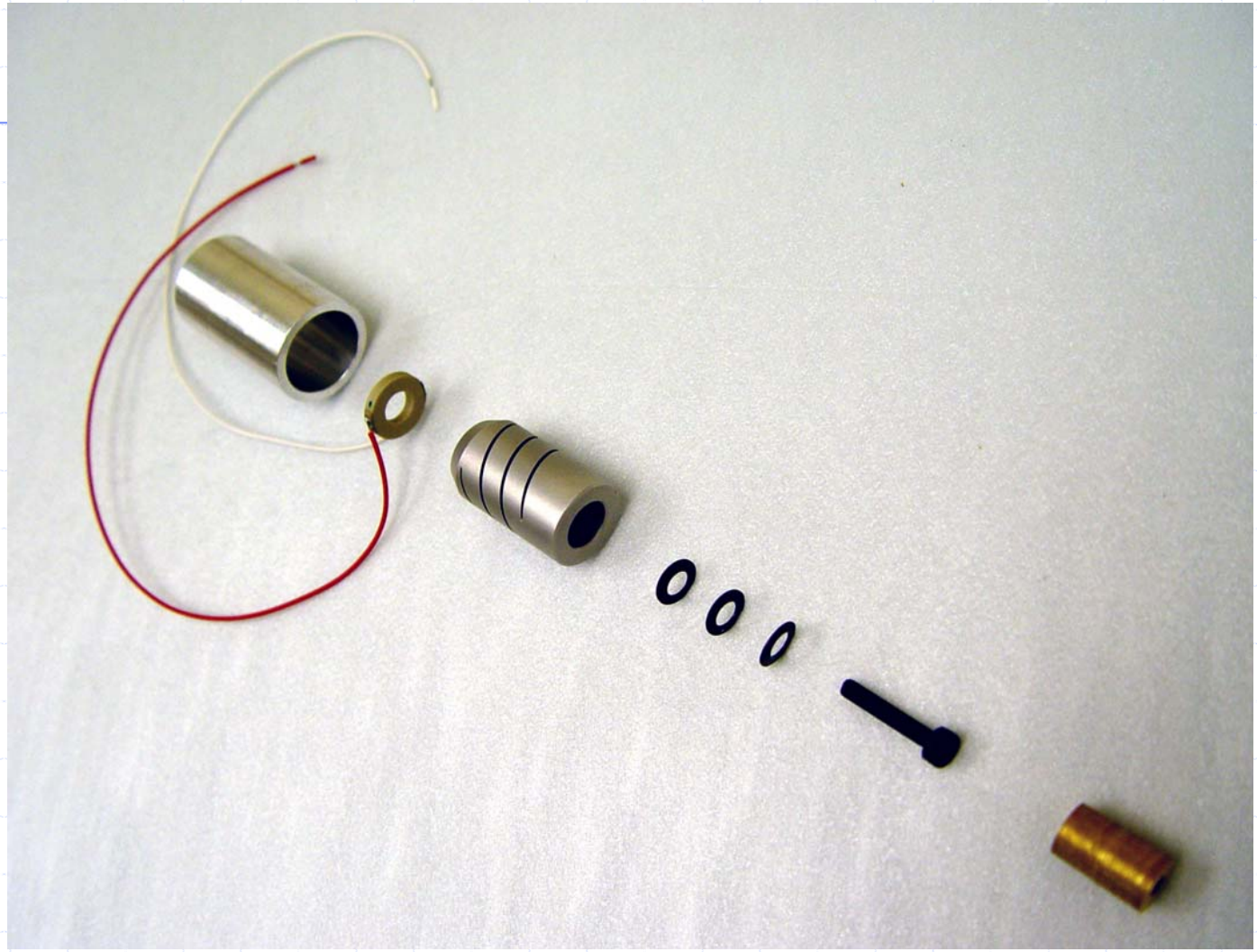
F = 2500 lbs generated by a spring deflecting 0.25 in = 6250 X 10^{-10} m

Since Energy = Deflection X Force



For a 1.8 preloading factor, and since only 1/3 of mechanical energy in piezo is electrical energy, the energy converted by the resonating unit is up to (1.8 X 6250 X 3 / 12.5) = 2700 times higher

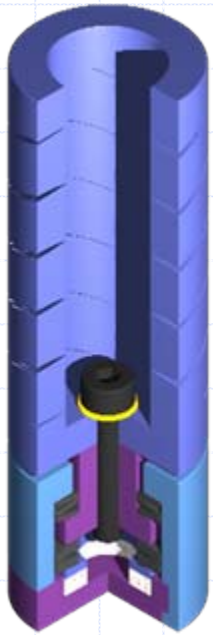
Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

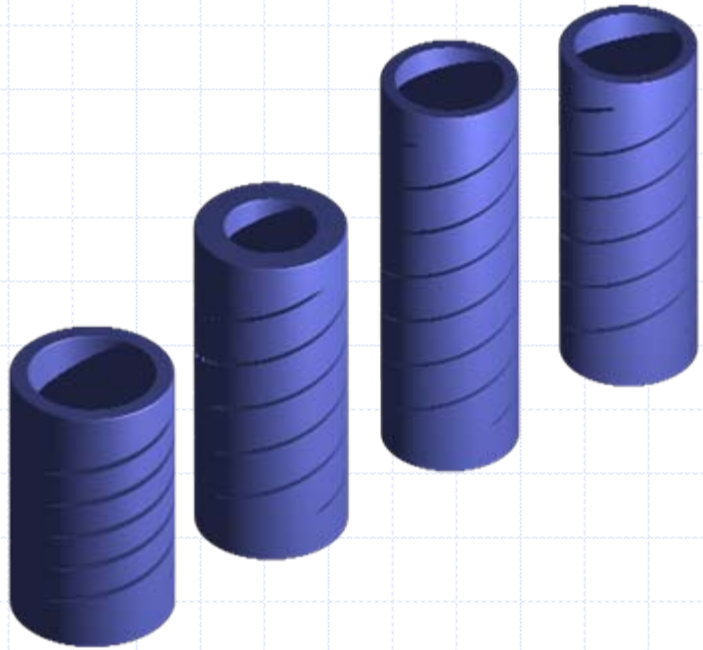


Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

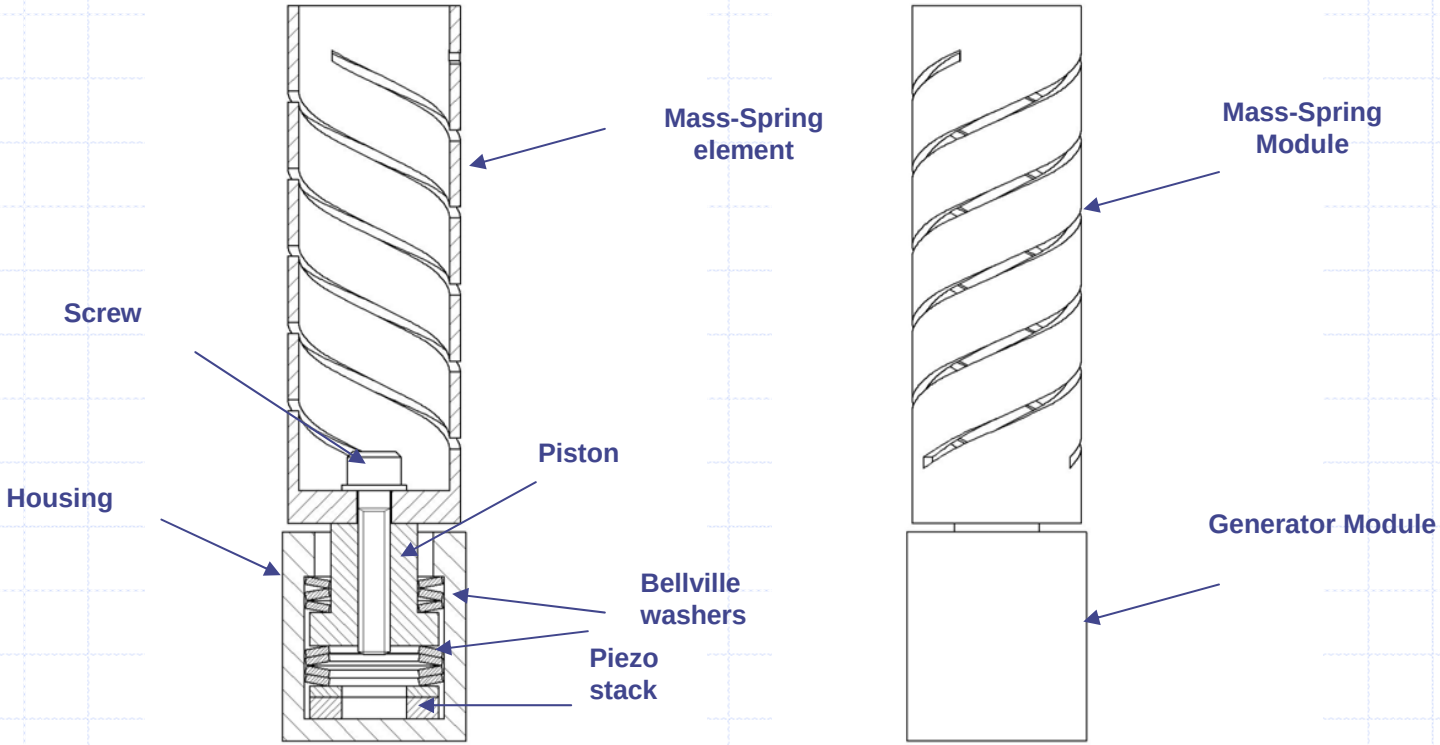
Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

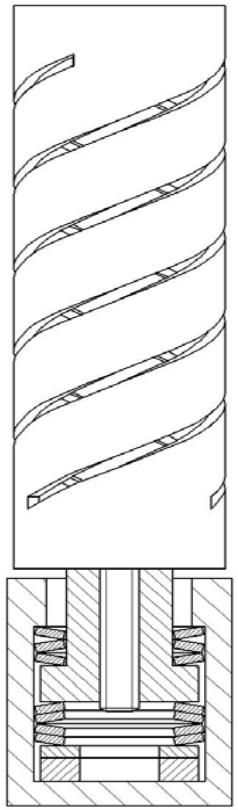


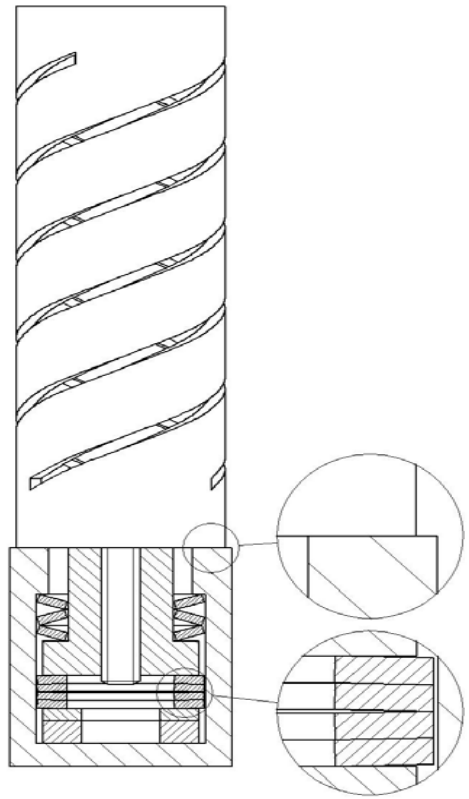


Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

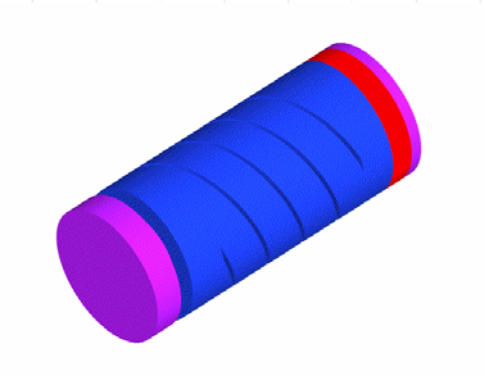


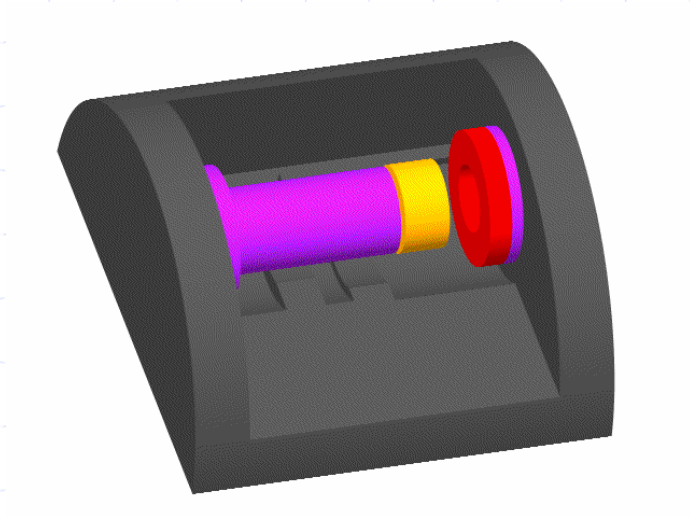
Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

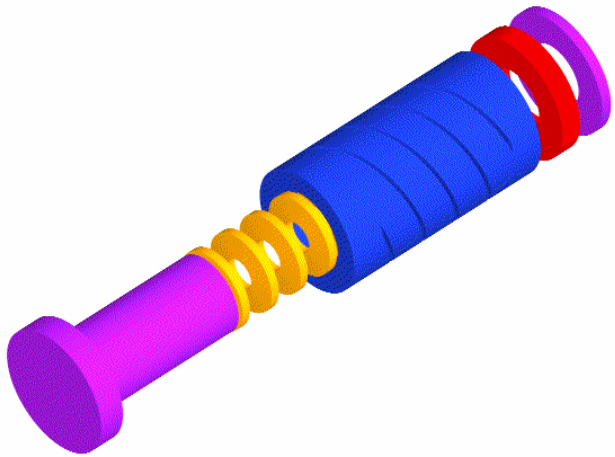




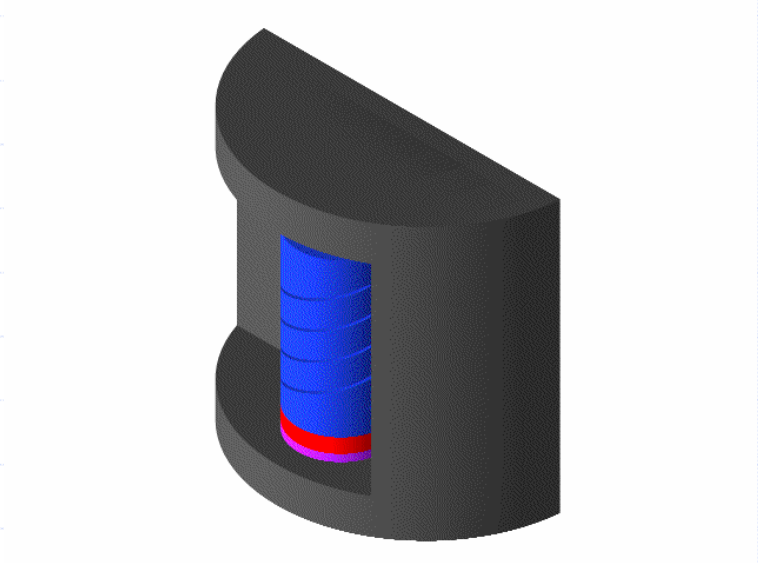
Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

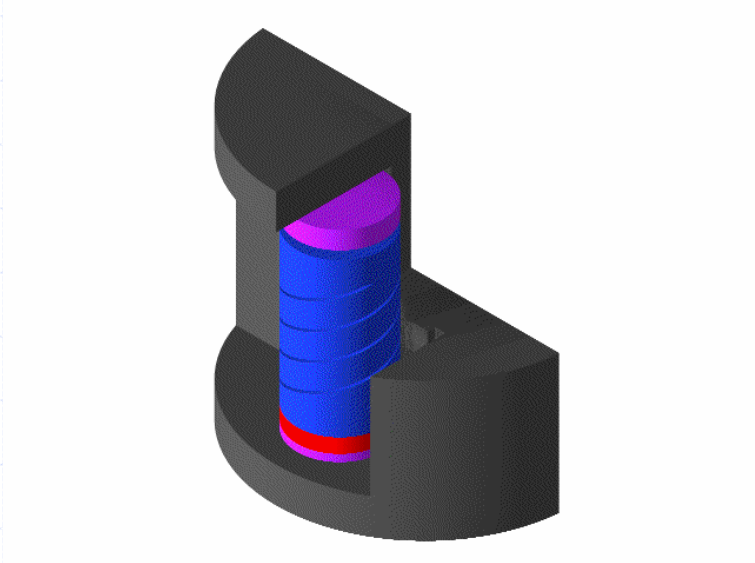




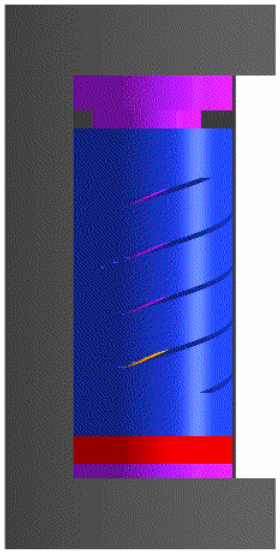


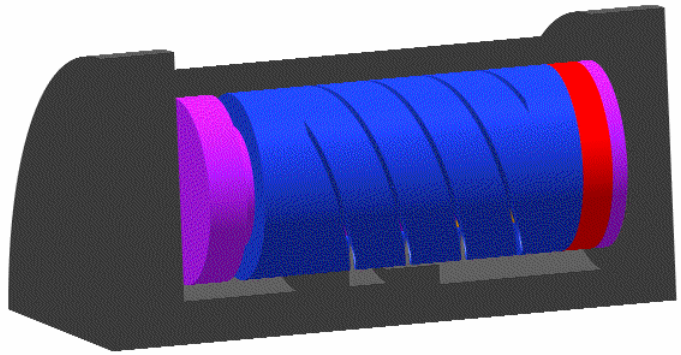
Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706





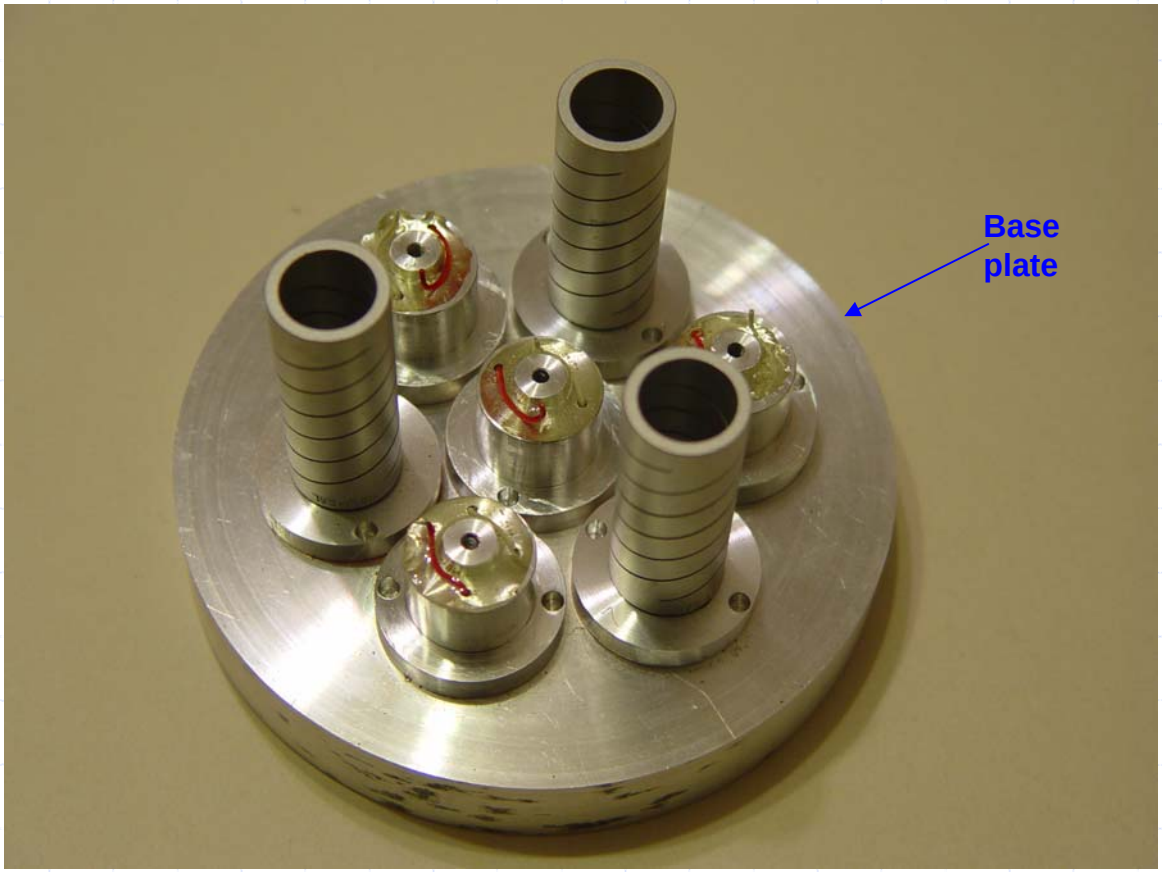
Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706



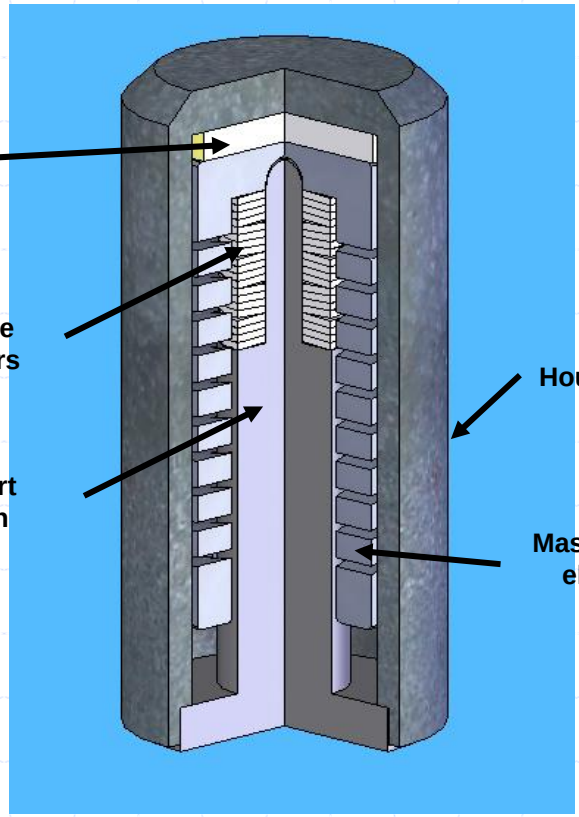


Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

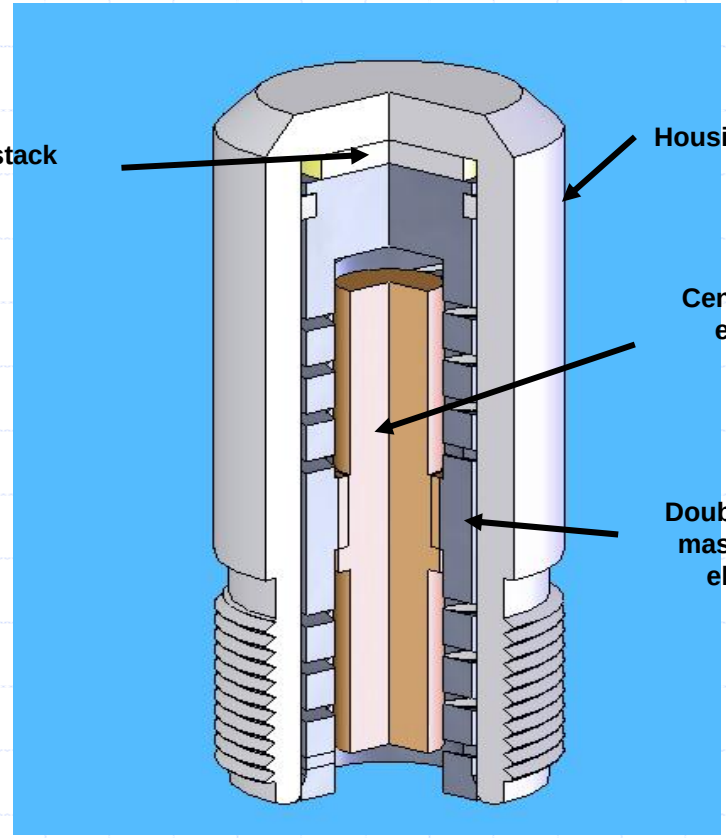
Piezoelectric-Based Energy Harvesting Power Sources for Gun-Fired Munitions



Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706



Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706



Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706

Advantages of Using Piezoelectric-Based Energy Harvesting Power Sources in Munitions

1. Safety (no initial power).
2. Very long shelf life.
3. Relatively small.
4. Can replace the onboard battery or reduces the total onboard battery and/or capacitor volume.
5. Operates in a wide range of temperatures.
6. May be integrated into the structure of munitions.
7. The level of output voltage provides information about the state of the munitions and can be used as secondary means for fuzing safety and munitions operation.

Conclusions

- Piezoelectric-based energy harvesting power sources have been developed for munitions for harvesting energy from firing acceleration and vibration during the flight.
- Generators that can generate over 2-5 J have been developed and will be test fired shortly.
- Prototypes have been constructed and tested at 13,000, 34,000 and 42,000 Gs using air-guns.
- The designs are modular and can cover a wide range of power requirements and can be shown to be capable of replacing chemical batteries in several fuzing applications.
- The power sources may be designed in almost any shape to fit the available space and even be integral part of the munitions structure.
- The power sources may also be designed to resonate in torsion or bending.

Omnitek Partners, LLC
111 West Main Street
Bay Shore, New York 11706