SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION XI

- DETONATORS
- FIRING SYSTEMS
- NEUTRONS INITIATION
- POWER SUPPLIES
Topics to be discussed

- Review of implosion assembly (IA) operation
- Review of stockpile detonators
- Firing system components
- Operation of explosive firing sets
- Stockpile firing sets
- Nuclear safety
- Production
- Future systems
Assumptions for briefing

- Students have an undergraduate background in engineering or science
Basics of an Implosion Assembly (IA)
Typical hot wire detonator
(Firing current ~ 5 amps)

- RDX or PETN
  Density ~ 1.65 g/cc
  8300 M/sec

- Lead Styphnate
  Density ~ 3.0 g/cc
  5200 M/sec

- Lead Azide
  Density ~ 4.0 g/cc
  5100 M/sec
An exploding bridgewire (EBW) detonator (1.5 X 40 mil gold) initiation requires ~ 300 amps

RDX or PETN
Density ~ 1.65 g/cc
8300 M/sec

PETN
Density ~ 0.85 g/cc
5000 M/sec
A basic exploding foil initiator (EFI), slapper detonator, consists of three components

Secondary Explosive Pellet
(Typically HNS IV)

Insulating disk with barrel (hole)

Etched metal foil with insulated flyer
The Mechanical Safe and Arm Device (MSAD) controls the detonator pellet in the W84 and W87.
EBW and EFI comparison for detonators which requires approximately the same initiation energy

<table>
<thead>
<tr>
<th></th>
<th>Exploding Bridge Wire</th>
<th>Exploding Foil Initiator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>250 mJ</td>
<td>250 mJ</td>
</tr>
<tr>
<td>Current</td>
<td>1000 Amps</td>
<td>2,500 Amps</td>
</tr>
<tr>
<td>Function time</td>
<td>2.0 μs</td>
<td>0.5 μs</td>
</tr>
<tr>
<td>Energy coupled into explosive</td>
<td>~20% of stored energy</td>
<td>~5% of stored energy</td>
</tr>
<tr>
<td>Explosive</td>
<td>PETN (0.8 gm/cc)</td>
<td>HNS (1.6 gm/cc)</td>
</tr>
<tr>
<td>HE melting point</td>
<td>140°C</td>
<td>320°C</td>
</tr>
<tr>
<td></td>
<td>(100°C degrades)</td>
<td>(doesn’t degrade)</td>
</tr>
</tbody>
</table>

* EBWs need recovery; slappers don’t.
* Slappers are more environmentally rugged.
Firing set provides: 1) Low to high voltage/current conversion; 2) Fuze/Fire interface; & 3) Det/NG interface

{Arming, Fuzing and Firing (AF&F)}
What is a capacitor? Basically two conductors separated by a dielectric

Energy = \( \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C} \)

- Q is the charge in coulombs
- C is the capacitance in farads
- V is the potential in volts
High voltage firing set capacitor
(High Energy Density (HED) capacitor)
Tradeoff of dielectric strength and dielectric constant - at field use condition

Dielectric Strength (Volts/mil)

Dielectric Constant

MICA PAPER
PAPER
D Ry MYLAR
FC-40 MYLAR
OIL
CERAMIC

0.01
1
10
100
1000
Firing set capacitor bank for a large number of detonators
Examples of high energy density capacitors
Basic operation of a switch tube

- High Voltage
- Capacitor
- Trigger
- LOAD
Vacuum and gas switches
Technology shift has led to reduced complexity and more repeatable processes

1. Fab/Test Cycle Time ~ 2-4 months
2. Unit Cost ~ $2-3K
3. Facility Space ~ 65,000 sq. ft.
4. Facility Cost ~ $5M
5. Multiple operations to closure

1. Fab/Test Cycle Time ~ 2-4 weeks
2. Unit Cost ~ $200-400
3. Facility Space ~ 5,000 sq. ft.
4. Facility Cost ~ $1M
5. Single Step closure
Explosive tack switch system - (Solid dielectric switch (SDS), Explosively driven switch)
There are two technology areas that have been employed in the stockpile

- Capacitor Discharge Unit (CDU) Firing Set
  - Typically all electric
  - Re-testable when it is all electric
- Explosive-to-Electric Transducers (EETs)
  - Chemical energy from explosives are used in the production of electrical energy
  - Single pulse or one shot device
Ferroelectric (FE) material retains a bound charge like a capacitor retains a surface charge.

Energy = \( \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C} \)
Bound charges are formed in a ferroelectric (FE) material during poling process

Unpoled Ceramic
Polycrystalline multidomain ferroelectric ceramic

Polling Process
Domains aligned by impressing external electric field
A shock wave of the correct magnitude releases bound charges in ferroelectric (FE) material.

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**Poled Ceramic**
Bound surface charge remains due to internal electric field.

**Shock Depoling Process**
Shock wave randomizes dipoles eliminating internal field, thus freeing bound charge to external circuit.
Ferroelectric firing set

B54 and/or Isolator

Define isolator and where it is used and why it is used
Slim Loop Ferroelectric (SFE) material reduces remnant polarization to fraction of a micro coulomb

Energy = 1/2 CV^2 = 1/2 \frac{Q^2}{C}
MC3028 Firing set
## Firing set technology comparisons

<table>
<thead>
<tr>
<th>Firing Set Technology</th>
<th>Typical Application</th>
<th>Relative Advantages</th>
<th>Relative Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDU</td>
<td>Bombs &amp; Cruise missiles</td>
<td>Retestable no HE</td>
<td>Special effort to Harden</td>
</tr>
<tr>
<td>FE</td>
<td>Isolators</td>
<td>Power source not required, small, inherently rad hard</td>
<td>HE required Stored energy</td>
</tr>
<tr>
<td>SFE</td>
<td>Missiles (RBs, RVs)</td>
<td>Small, inherently rad hard</td>
<td>HE required Requires trigger</td>
</tr>
<tr>
<td>FM</td>
<td>Artillery shells (AFAPs)</td>
<td>Fastest arm/disarm Small, rad hard</td>
<td>HE required</td>
</tr>
<tr>
<td>CMF</td>
<td>Under ground testing (UGT)</td>
<td>Large output current &amp; energy, rad hard</td>
<td>Long function time, HE required, requires timed trigger</td>
</tr>
</tbody>
</table>
Firing sets have many complex requirements beyond that of initiating detonators

- Firing set complexity may be driven by
  - Nuclear safety
  - Radiation
  - Use control
  - Housing/mounting for other components
  - Testability
  - Manufacturability
  - Cost

- There may not be syneresis between requirements
Nuclear safety requirements require the implementation of several complex features

<table>
<thead>
<tr>
<th>Principles</th>
<th>Implementation</th>
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<tbody>
<tr>
<td>Isolation</td>
<td>Barriers, Strong links</td>
</tr>
<tr>
<td>Inoperability</td>
<td>Weak links, Colocation</td>
</tr>
<tr>
<td>Incompatibility</td>
<td>Unique signal operated devices</td>
</tr>
<tr>
<td>Independence</td>
<td>Multiple independent safety subsystems</td>
</tr>
</tbody>
</table>
Firing system with enhanced nuclear detonation system (ENDS) features
Capacitor technology - tradeoff of thermal weak link properties and radiation properties
Packaging of the printed wiring assembly (PWA) in the B83 firing set before "sylgard 184 GMB"
Packaging of the printed wiring assembly (PWA) in the B83 firing set after "sylgard 184 GMB"
Simple nuclear weapon firing set

NG

Trigger
NG HV

Prearm

Voltage Conversion

Capacitor

Sprytron

Load

Trigger
Firing systems in the active stockpile
Firing sets and detonators in the active stockpile
Firing set production is ongoing at a low level

<table>
<thead>
<tr>
<th>Weapon</th>
<th>MC Number</th>
<th>Technology</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>B83</td>
<td>MC3971A</td>
<td>CDU</td>
<td>~ 10/month ongoing</td>
</tr>
<tr>
<td>W87</td>
<td>MC3719</td>
<td>CDU</td>
<td>~ 3-4/month starting 1998</td>
</tr>
</tbody>
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