Explosives & Initiation systems
Harald Bornebroek
Orica Mining Services

• The world’s largest supplier of commercial explosives
  • 28% market share – 50 countries
  • 4 mil. tons of bulk explosives, 10,000 tonnes/d, 1,500 blasts/d
• Pioneers of new technology
• Advanced blasting solutions tailored to specific customer needs and challenges
• Regional offices in Australia, Asia, Europe, the Middle East, Africa, North America and Latin America
• Partnering Customers in open cut coal, open cut metal, underground mining, seismic, avalanche, quarrying and construction markets
Explosive Properties
Explosion

...a rapid expansion of matter into a volume much greater than the original volume.
Explosive

...a combination of various substances and mixtures that produce a rapid exothermic reaction when initiated.
All Explosives Composed of -

- Oxidizer
- Fuel
Explosive Properties

All Explosives Require Fuel and Oxidizer
Explosive efficiency is dependent on intimacy of fuel/oxidizer contact...

Smaller Particles → More Efficient
Emulsion Matrix

“internal“ Phase

Ammoniumnitrate solution
ca. 91 to 95%

Oxygen

“external“ Phase

Oil & Emulsifier
ca. 5 to 9%

Fuel

+ Energy

= Emulsion (Emulsionsmatrix - EP)
Dispersed Droplets of Oxidiser Solution (AN) in a Matrix Fuel Phase (FO).

Emulsifier bonds the Oxidiser and Fuel.

Droplets the size of Fog / Mist.

3/1000 mm
EXPLOSION PROCESS

1. Oxygen Supply
2. Fuel
3. Heat / Booster
4. Detonation Pressure

Explosion
Sensitising

And what makes the **ANE MATRIX** into an EXPLOSIVE?

**Physical sensitisation**
- Glass Micro Ballons (GMB)

**Chemical sensitisation**
- Gas bubbles ("Chemical-Gassing")
Unsensitised Matrix          Sensitized Matrix

Oxidizer
5.1     1.5
"HOT SPOTS"

A

Shock waves

Bubbles

B

Impact
"HOT SPOTS"

C) Primer → Impact → Bubbles

D) Intense "Hot Spot" → Ongoing
Molecular Explosives

Oxygen and Fuel In Molecule, not just mechanically mixed

PETN
TNT
HMX
Detonation

A specific type of explosion consisting of an exothermic reaction which is always associated with a shock wave.
DETONATION PROCESS

1 Litre = 1.25 kg

Initiation

Gases

1000 Litres

= 5 X 200L
Important Characteristics of a Detonation

- Fast Release of Energy
- Generates Shock Wave
- Generates Large Gas Pressure
Blast Resultants

Crushing Around the Borehole Wall: 
Crack Formation: 
Shearing: 
Heat and Light: 
Mass Movement: 
Ground Movement: 
Air Blast: 

Total: 100 %
Undesirable Blasting Effects

- Air Blast
- Ground Vibration
Explosive Properties

- Velocity of Detonation
- Density
- Detonation Pressure
- Borehole Pressure
- Sensitivity
- Energy
- Pressure Tolerance
- Safety
- Temperature Affects
- Post Blast Fumes
- Shelf Life
- Water Resistance
Velocity of Detonation

The Rate at which the Detonation Wave Travels Through an Explosives Column

Graph showing velocity of detonation with time (ms) and distance (ft). The graph indicates a velocity of 1474 ft/sec.
Factors Affecting Detonation Velocity

- Oxidizer - Fuel Interface
- Confinement
- Temperature
- Product Density
- Product Diameter
- Oxygen Balance
Density

Grams per Cubic Centimeter

ANFO Density 0.84 g/cc

Emulsion Matrix 1.4 g/cc
Density Control

Add Microballoons or Air/Gas

Emulsion Matrix
1.4 g/cc

+ Density Control =

Emulsion Explosive
1.2 g/cc
Detonation Pressure

A Function of Density and Velocity of Detonation

Density x (VOD)^2
## Detonation Pressures

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Pressure (kbars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANFO</td>
<td>34</td>
</tr>
<tr>
<td>Water Gel</td>
<td>76</td>
</tr>
<tr>
<td>Emulsion</td>
<td>100</td>
</tr>
<tr>
<td>Ammonia Gelatin Dynamite</td>
<td>135</td>
</tr>
<tr>
<td>Pentolite Cast Booster</td>
<td>240</td>
</tr>
</tbody>
</table>
BLAST EFFECTS

- Gunpowder
- ANFO
- Senatel
- Pentex Booster

Steel plate
Booster on Steel Plate
EXPLOSIVES ENERGY

• Shock Energy -- Affects Fragmentation
• Gas Energy -- Affects rockpile Looseness & Digability
Energy Partitioning

- Shock Energy
- Gas Energy

Graph showing the relationship between pressure and volume.
Shock Energy
Gas Energy
Absolute Weight Strength (AWS)

The Absolute Amount of Energy Available In Each Gram of Explosive
Absolute Bulk Strength (ABS)

The Absolute Amount of Energy Available In Each Cubic Centimeter of Explosive
Relative Weight Strength (RWS)

Compares Explosive Energy per Weight to the Energy of an Equal Weight of ANFO
Standard ANFO

RWS = 100
Relative Bulk Strength (RBS)

Compares Explosive Energy per Volume to the Energy of an Equal Volume of ANFO
ENERGY RATINGS

**R W S**
- Same mass
- ANFO: 1 kg, R W S = 100
- Fortis: 1 kg, R W S = 101
- Relative Weight / Bulk
  - Same volume

**R B S**
- ANFO: 1 kg, R B S = 100
- Fortis: 1.5, R B S = 151
Sensitivity

Ease of Initiation by . . .

*Shock*
*Impact*
*Friction*
*Heat*
Sensitivity

Ability to Propagate

Gap Sensitivity
UN Classifications for Explosives

1.1 Detonator Sensitive Explosive

1.4 Detonating Devices

1.5 Booster Sensitive Explosive

5.1 Oxidizer
Water Resistance

The Ability of an Explosive to Withstand Exposure to Water
WATER RESISTANCE

1. Detonators
2. PENTEX Boosters
3. Packaged Emulsion
4. Bulk Emulsion
5. Emulsion/ANFO Blends
6. ANFO
Blasting Fumes

Harmless and Harmful...

Carbon Dioxide  Carbon Monoxide
Water Vapor      Nitrous Oxides
Nitrogen        Hydrogen Sulfide
Oxygen
OXYGEN BALANCE

O₂ Balanced
- Correct fuel

O₂ Negative
- Too much fuel

O₂ Positive
- Too much oxygen

Nitrates (O₂)  Fuels

- CO₂
- N₂
- H₂O

- CO
- N₂
- H₂O

- CO₂
- NOₓ
- H₂O
NOx Post Blast Fume
EXPLOSIVES SELECTION CRITERIA

What must I consider?

- Ground water conditions
- Rock properties
- Hole diameter & depth
- Drilling capacity / costs
- Rel. explosive costs per unit of effective energy
- Fragmentation & Heave characteristics
- Shelf life
- Desired results
Definition

An Initiation System …
… is a means of detonating high explosive charges **reliably**, at the specified **time** and in the correct **sequence** ....
Nonelectric Initiation

Mode of Operation

1. Shockwave travelling thru Shock Tube
2. Initiation of Pyrotechnic Element
3. Detonation of Primary Charge or DDT Element
4. Detonation of Base Charge
Nonelectric Initiation
Shock Tube Functioning

Shock Tube
Flame Front
Shock Wave preceding Flame Front
HMX / Al dust
Nonelectric Initiation
Shock Tube Construction

- Multiple Layers Tubes
- HMX / Al Dust Mixture
- Coreload Limits $\approx 15 \text{ mg/m}$
Nonelectric Initiation
Shock Tube – Live & Fired
Nonelectric Initiation
Shock Tube vs. Detonating Cord

\[ \approx 2,000 \, \text{m/s} \]

\[ \approx 6,500 \, \text{m/s} \]
Nonelectric Initiation

3 Areas of Initiation System

**Starter**
- the key....

**Surface**
- the distributor....

**In hole**
- the transmission....
Nonelectric Initiation

Surface Delay vs. Detonator Strength

Surface Delay

#2
0.2 g Pb Azide

Detonator MS - LP

#8
0.125 g Pb Azide
0.78 g PETN
Nonelectric Initiation
Surface Delay vs. Detonator
Nonelectric Initiation
Detonator Assembly
Nonelectric Initiation
Surface Delay - Construction

- Base Charge (e.g.: ≈ 200 mg of Lead Azide)
- Delay Element
- Isolation Cup
- Free Space
- Crimp
- Rubber Bush
- Shock Tube
Nonelectric Initiation
Surface Delay - Construction
Nonelectric Initiation
Function Surface Delay

+ 17 ms

+ 17 ms
Nonelectric Initiation
In Hole Timing

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
<th>Time 4</th>
<th>Time 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 ms</td>
<td>500 ms</td>
<td>500 ms</td>
<td>500 ms</td>
<td>500 ms</td>
</tr>
<tr>
<td>+ 17 ms</td>
<td>+ 17 ms</td>
<td>+ 17 ms</td>
<td>+ 17 ms</td>
<td>+ 17 ms</td>
</tr>
<tr>
<td>= 517 ms</td>
<td>= 534 ms</td>
<td>= 551 ms</td>
<td>= 568 ms</td>
<td>= 585 ms</td>
</tr>
</tbody>
</table>
Nonelectric Initiation

Electric Initiation of Nonelectric Blast
Nonelectric Initiation

Nonelectric Initiation of Nonelectric Blast
Detonating Cord
Cord Construction

- PETN Core
- Centre Cottons
- PP Yarns
- Plastic Over Extrusion
- Overwrap Yarns
- Waxed Overcoat
### Detonating Cord

#### Cord Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Diameter (g/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Cordtex’ 3.6 ‘W’</td>
<td>Uniflex 3.6 g/m</td>
</tr>
<tr>
<td>‘Cordtex’ 5 ‘W’</td>
<td>5 g/m</td>
</tr>
<tr>
<td>‘Cordtex’ 5 ‘P’</td>
<td>5 g/m</td>
</tr>
<tr>
<td>‘Cordtex’ 10 ‘P’</td>
<td>Redcord 10 g/m</td>
</tr>
<tr>
<td>‘Profiler’</td>
<td>70 g/m</td>
</tr>
</tbody>
</table>

[Image of detonating cords with labels and diameters]
Detonating Cord
MS Connector

to Fire detonating cord ONLY
Detonating Cord
MS Connector

- Plastic Cleat Blocks
- 25ms
- Yellow EXEL signal tube
- Nonelectric delay detonator
- Delay Range:
  - 9ms
  - 17ms
  - 25ms
  - 42ms
  - 65ms
  - 100ms
  - 125ms
  - 150ms
  - 175ms
  - 200ms

# 8 Strength cap
to Fire detonating cord ONLY
Nonelectric Initiation
Nonelectric Initiation vs. Initiation via Detonating Cord
Nonelectric Initiation

Pro´s and Con´s

Pro:
+ easy handling,
+ no extra tool required,
+ ruggedized,
+ safe against stray current,
+ no risk of Leakage,
+ no system limits,

Contra:
– no Circuit Testing,
– additional element: Surface Delay,
– Calculation of the real firing time,
– accuracy,
– Shock Tube can not be shortened/cut,
– Shock Tube waste in muck pile.
Electric Initiation

Mode of Operation

**Instantaneous Detonator**
- Initiation of Fusehead
- Detonation of Primary Charge
- Detonation of Base Charge

**Delay Detonator**
- Pyrotechnic Delay
- Detonation of Primary Charge
Electronic Initiation

Detonator Construction

- Wire
- Sealing Plug
- Safety
- Chip on Board
- Capacitor
- Fuse Head
- Shell
- Base Charge
Electronic Initiation
Precision & Value
Electronic Initiation
Influence of Timing on Wave Frequency

High frequency – Choppy
Ship is smooth - Don’t feel anything

Low frequency – Swell
Ship rolls - Unpleasant
Electronic Initiation
Benefits of Electronic Initiation

• Smooth walls - reduced back break
• Improved fragmentation - reduced fines
• Improved vibration control
• Precise control over rock pile heave
• Unlimited timing possibilities