New Leaders' Conference 2004

The Evolution of the Detonator

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Wednesday 21st April, 2004

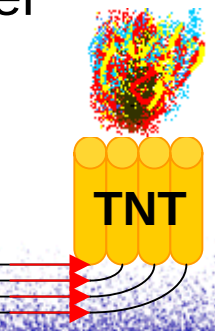
PRESENTATION OVERVIEW

- Background
- History
- Evolution
  - Plain, Electric, Electric Delay, Detonating Cord, NONEL® and Electronic
- Future Advancements
- Summary

The Evolution of the Detonator

BACKGROUND

- Detonator is a device designed to explode and initiate a high explosive
- Contain sensitive explosive charges encased in cylindrical metal shell
- Various detonators categorised with respect to initiation signal energy source, i.e. non-electric, electric, electronic
- Different strengths dependent on amount of base charge contained and identified by strength number



The Evolution of the Detonator

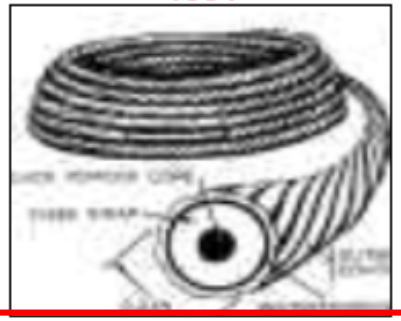
HISTORY

- Black powder first used to fragment rock in mining in early 1600s
  - Extremely dangerous as unreliable burning speed, resulting in many deaths
- Hazardous ignition overcome in 1831 with invention of ‘Miners Safety Fuse’ by William Bickford
  - Rope with a strand of yarn infused with black powder

1627

Black Powder First Used

1831



Invention of Safety Fuse

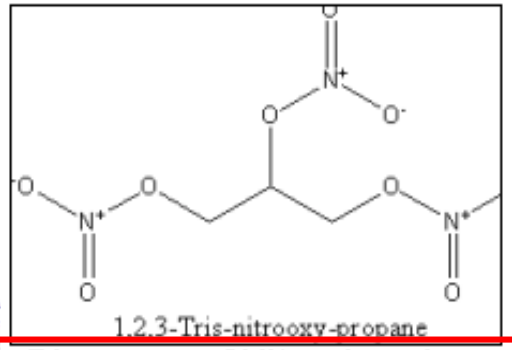
Mining initiation timeline

DYNO
Dyno Nobel

HISTORY

- Discovery of Nitroglycerine in 1846 by Ascanio Sobrero
- Safe manufacture in 1880s for industrial use
  - More powerful than black powder
  - Accidents resulted from borehole ignition by safety fuse and black powder

1846



Discovery of Nitroglycerine

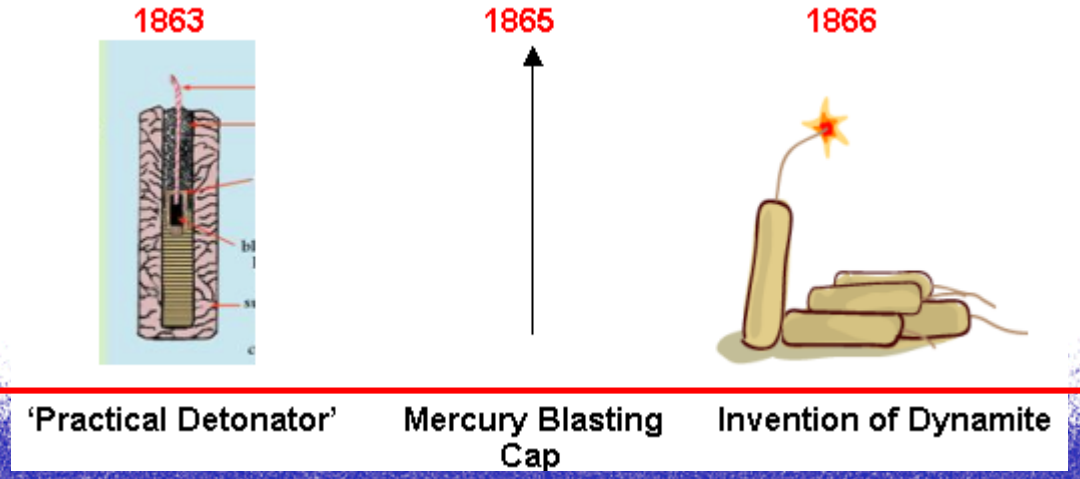
1860s

Manufacture of Nitroglycerine

The Evolution of the Detonator

HISTORY

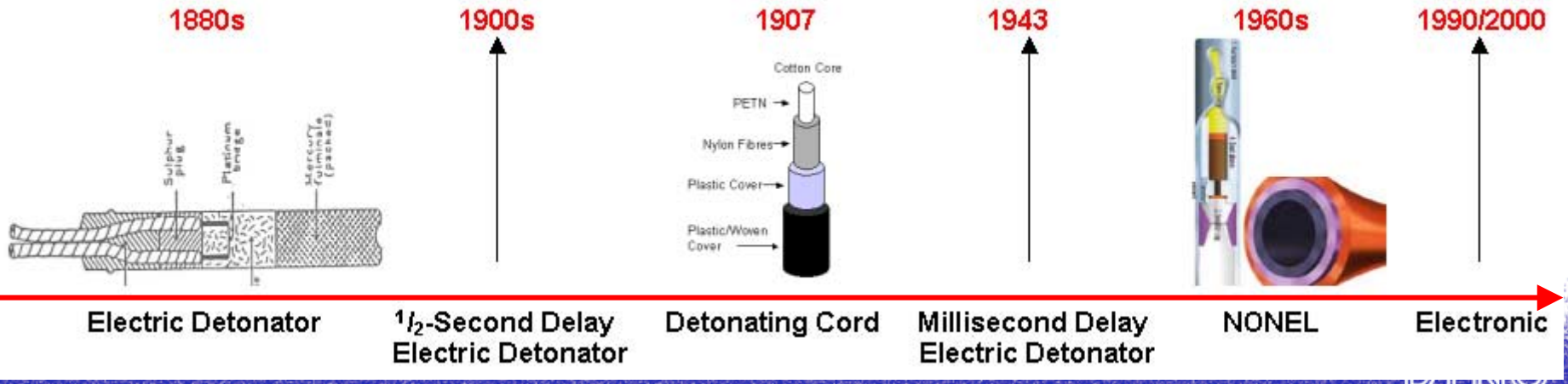
- Hazardous ignition overcome in 1863 with development of ‘practical detonator’ by Alfred Nobel
  - Wooden plug of black powder inserted into larger charge of liquid nitroglycerine, enclosed in metal shell
- Nobel experimented with design and eventually developed a mercury blasting cap in 1865



The Evolution of the Detonator

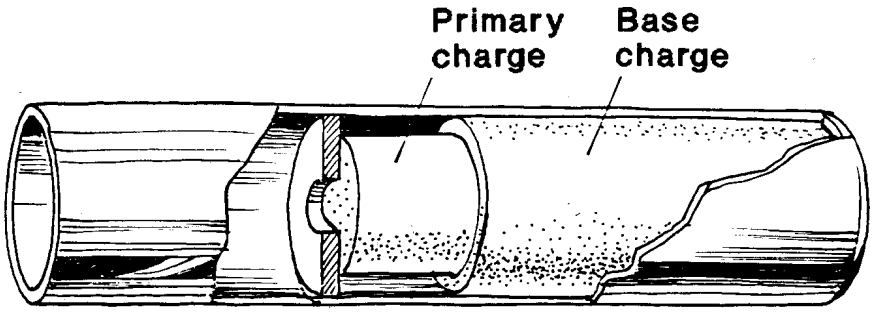
HISTORY

- Mercury blasting cap opened door for all subsequent high explosive use
- All detonator advancements based on original mercury blasting cap



EVOLUTION

- Plain Detonator
  - Substitution of expensive fulminate with a primary (initiating) charge and a base charge of high explosive
  - Primary charge of ASA
  - Base charge of PETN or RDX



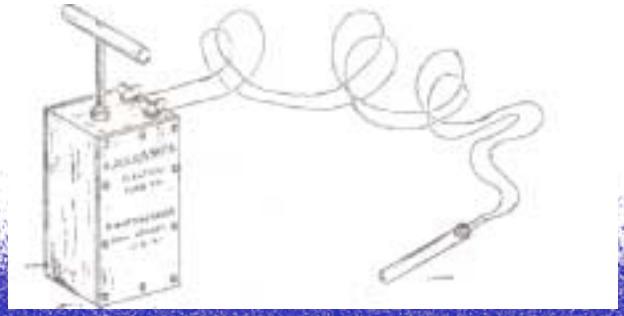
Plain detonator cross section (Olofsson, 1988)

EVOLUTION

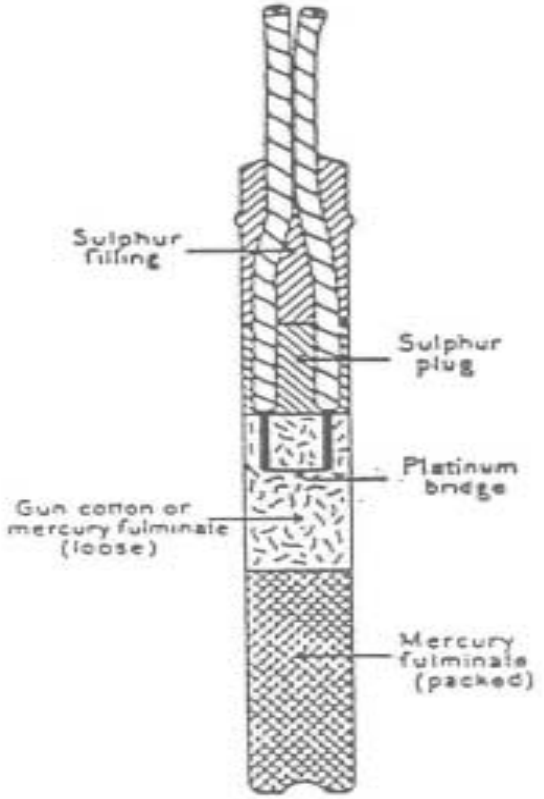
- Instantaneous Electric Detonator
  - First prototype emerged late 1880s
  - Replacement of safety fuse with electric wires connected to a fusehead
  - Initiation via electric current passed through leg wires

The Evolution of the Detonator

- Electric Detonator
  - Two cotton insulated leg wires, ignition mixture of mercury fulminate, high-resistance platinum bridge wire and a sulfur plug
  - Detonated via ‘the exploder’ patent by H. Julius Smith, making initiation easy and safe
  - Design changed slightly over the years



The exploder

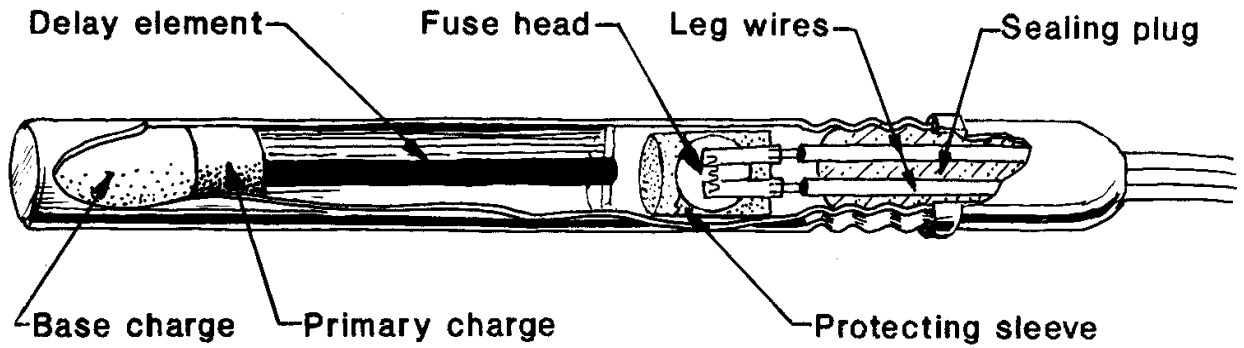


1880s electric detonator cross section

The Evolution of the Detonator

EVOLUTION

- Delay Electric Detonator
  - Same as instantaneous electric detonator, except for inclusion of delay powder train
  - Delay time based on length and composition of delay powder
  - Half-second delay early 1900s, millisecond delay 1943



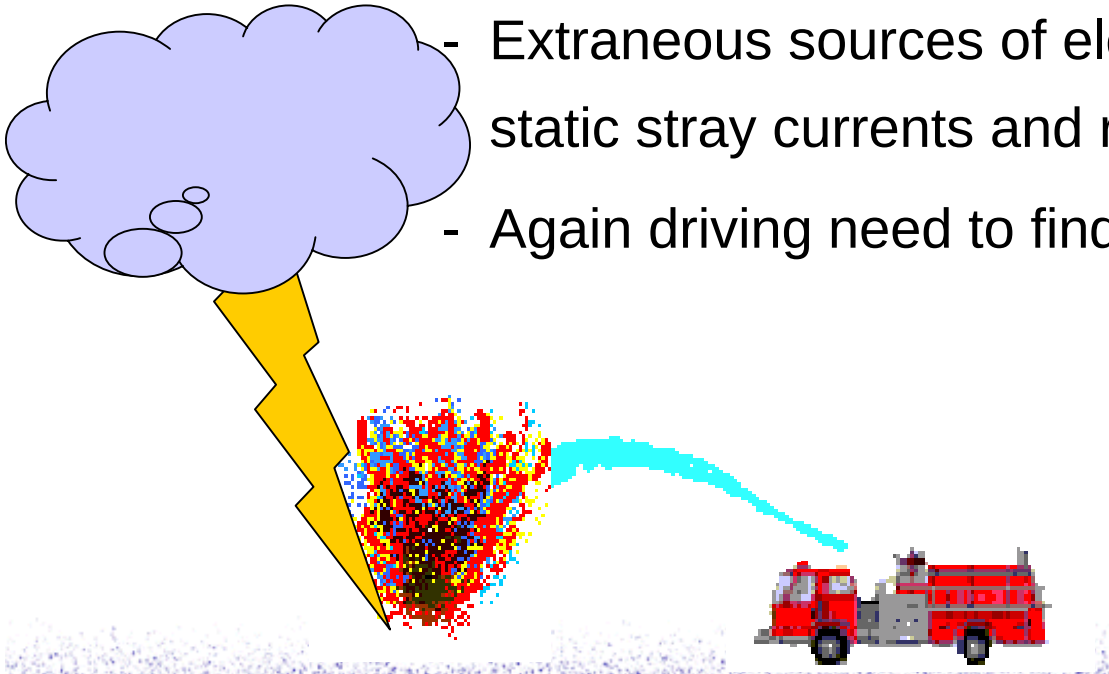
Electric delay detonator cross section (Olofsson, 1988)

ELECTRIC DETONATOR

- Advantages:
  - Higher degree of safety – remove blaster from shot
  - Total control of initiation time
  - Circuit Testing
  - Better results with delays - different applications such as bench, trench and tunnel blasting
  - Reduction in air blasts and ground vibration
  - Could be used in U/G gassy coal mines, where safety fuse was outlawed – copper substituted for aluminium

ELECTRIC DETONATOR

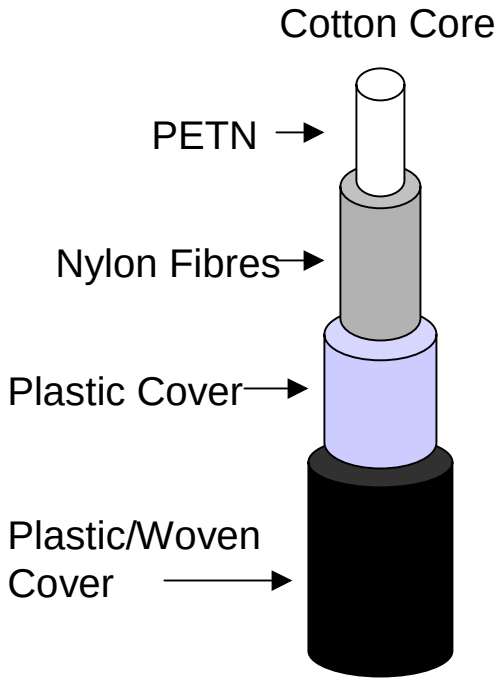
- Disadvantages
  - Risk of premature detonation!
  - Extraneous sources of electricity such as lightning, static stray currents and radio frequency energy
  - Again driving need to find alternative initiation system



The Evolution of the Detonator

EVOLUTION

- Detonating Cord
  - Strong, flexible, continuous detonator
  - Developed in 1907 in France and called Cordeau
  - Consisted of lead tube enclosing TNT, burning at 4900m/s
  - Nowadays, PETN cotton core surrounded by various textile combinations, plastics and waterproofing materials
  - Burning speed in excess of 7000m/s



Detonating cord make

DETONATING CORD

- Advantages:
  - Versatile, safe for use in extraneous electricity environments, simultaneously firing without detonators, no hole limit, totally consumed, inexpensive
  - Incorporation of delay connector in 1950, allowed sequential blasting of larger patterns than electric
- Disadvantages:
  - Noisy initiation, large amount of cord movement, disruption to stemming column when down the hole

EVOLUTION

- NONEL
  - Total non-electric initiation system developed in 1960s by Dyno Nobel
  - Products hit the market in 1973, offering all the advantages of electric initiation and detonating cord but none of the disadvantages
  - Range included the NONEL detonator connected to NONEL tube along with surface and downhole delays and surface connectors

The Evolution of the Detonator

EVOLUTION

- NONEL
  - NONEL tube (shock tube) transmits shock wave to NONEL detonator
  - Shock wave results from tube coating of reactive powders and travels at 2100m/s
  - Minimal noise and cord movement

NONEL detonator cross section

DYNO
Dyno Nobel

NONEL

- Advantages:
  - Noiseless, still initiation, downhole delays, simplified tie-in patterns, no hole limit, reduction in air blasts/ground vibration, safe to use in extraneous electricity environments
- Disadvantages:
  - Lack of circuit testing
  - Expensive

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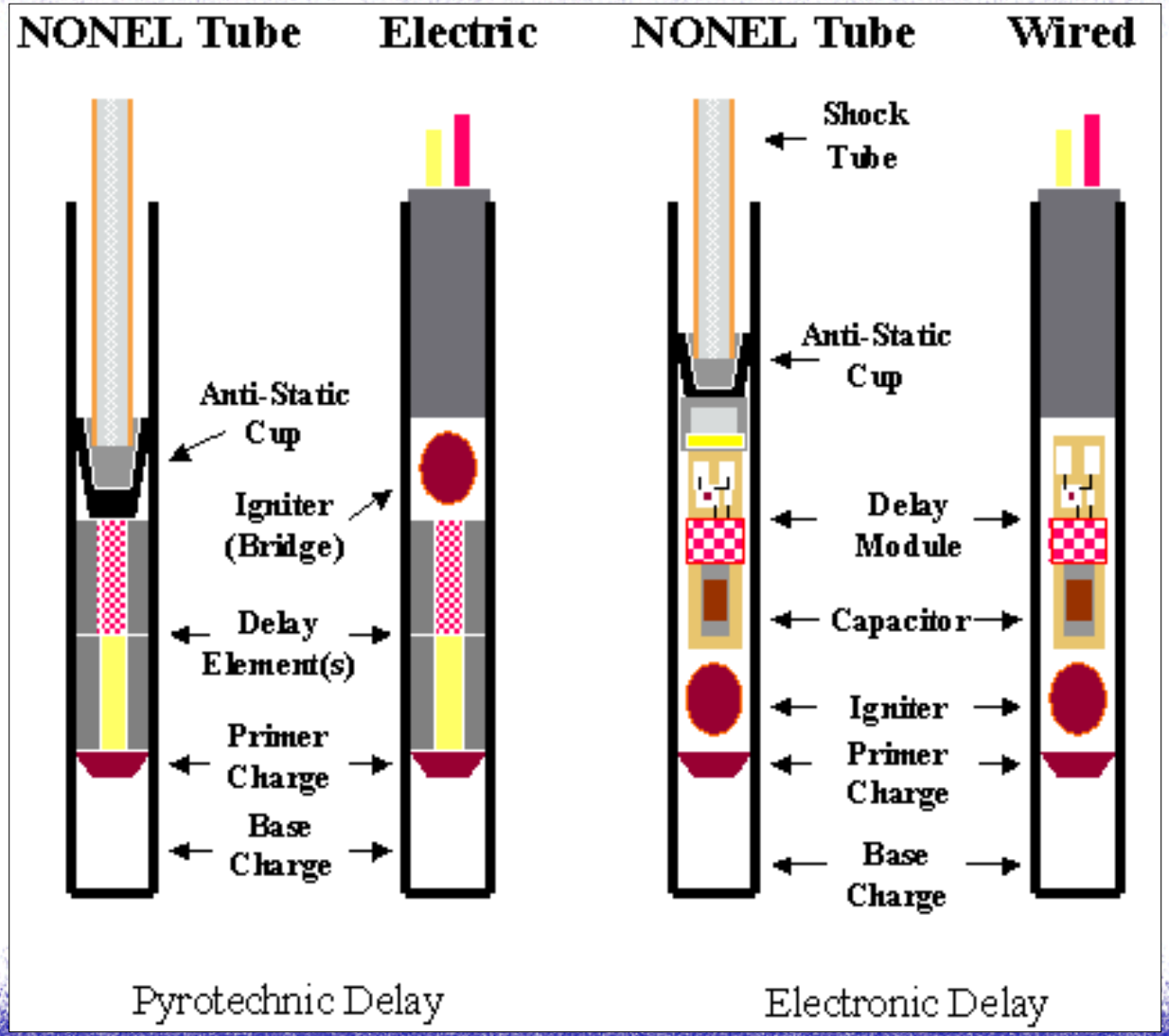
EVOLUTION

- Electronic
  - Idea of electronics first discussed beginning 1990s
  - Recognised potential to increase detonator accuracy and improve customer results
  - Costly technology served as a deterrent
  - Minesite drive to increase accuracy, resulted in various manufacturers beginning to develop and market versions of electronic detonators

EVOLUTION

- Electronic
  - Several different designs, fundamental structure basically the same
  - Computer chip used to control delay timing which uses electrical energy stored in one or more capacitors to provide power for timing clock and initiation energy
  - Therefore delay is achieved electronically not pyrotechnically (powder)

The Evolution of the Detonator



Detonator differences (Wiggin, 2003)

DYNO
Dyno Nobel

Electronic

- Advantages:
  - Higher precision
  - Improved blasting results (one to several thousand ms delay)
  - Reduce downstream costs
  - Increased flexibility (programming with LU in borehole)
  - Environmental – reduce air blasts/ground vibration
  - Streamline stock management
  - Circuit functionality testing (2-way communication with LU)
  - Used safely in extraneous electricity environments

Electronic

- Disadvantages:
  - Limit to the amount of detonators per shot (controlled by LU and Blasting Machine)
  - Increased cost per detonator unit
  - Intensive user training

FUTURE ADVANCEMENTS

- Original initiation advancements driven by need to increase miner safety
- However as mining became more competitive, better results and precision provided additional catalysts
- Today three main factors of initiation purchase:
    1. Price – Mining industry continually driving blast accessory prices down
    2. Ease of Product Use
    3. Reliability (Market Equity, 2002)

FUTURE ADVANCEMENTS

- Market Success:
  - Have to satisfy customer needs
  - Need to alter ‘why bother changing’ attitude
  - Provide ‘after sales service’
  - Design initiation system to achieve best desired results for particular purpose i.e, cast blasting, coal blasting, trench blasting, etc
  - Efficient, flexible and precise as productivity demands

FUTURE ADVANCEMENTS

- Electronic Initiation:
  - Needs to overcome increased cost
  - Present usage of the system requires intensive training and needs to be simplified, i.e. system needs to implement with ease, without major changes
  - The evolution of electronics needs to be based on customer needs!

The Evolution of the Detonator

SUMMARY

- Evolution of detonation systems has changed over the years based on customer needs
- Development of different systems for different customer markets
- Inclusion of electronic detonators will be challenging as customers have to be convinced of benefits
- As technology advances and customer needs change, detonation systems need to continue to be parallel to this to ensure market success