Explosive Products

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Choosing Optimum Explosive Type

- For Main Explosive Charge and/or Primer make-up
  - ✓ Critical diameter
  - ✓ Density
  - ✓ Sensitivity
  - ✓ Sensitiveness
  - ✓ Water resistance
  - ✓ Detonation velocity
  - ✓ Detonation pressure / Borehole pressure
  - ✓ Energy
  - ✓ Storage, Transportation and Loading/Handling
  - ✓ Value

Explosive Types – Main Explosive Charge

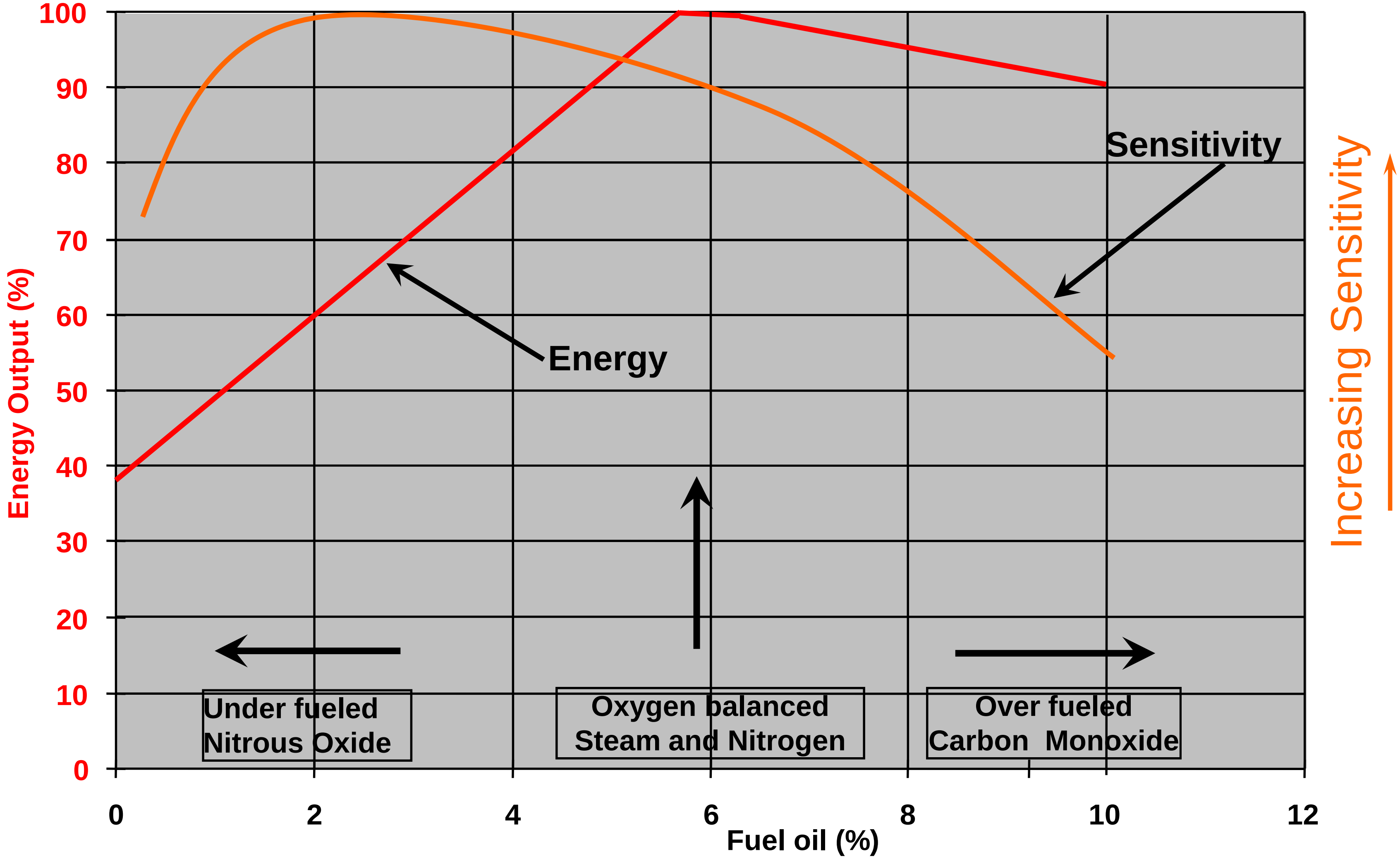
- **Bulk Explosives**
  - ✓ **Blasting Agent, 1.5 D (not detonator sensitive)**
    - ANFO
    - Heavy ANFO Blend (ANFO with 5% to 50% Pumpable Explosive or Non Explosive Matrix)
      - Water gel
      - Emulsion
    - Repumpable Emulsion ANFO Blend (Repumpable Explosive Matrix with 0% to 50% ANFO)
      - Water gel
      - Emulsion (available with chemical sensitization/field density adjustment)
    - Repumpable Explosive Matrix
      - Water gel
      - Emulsion (available with chemical sensitization/field density adjustment and/or viscosity adjustment)

Bulk ANFO

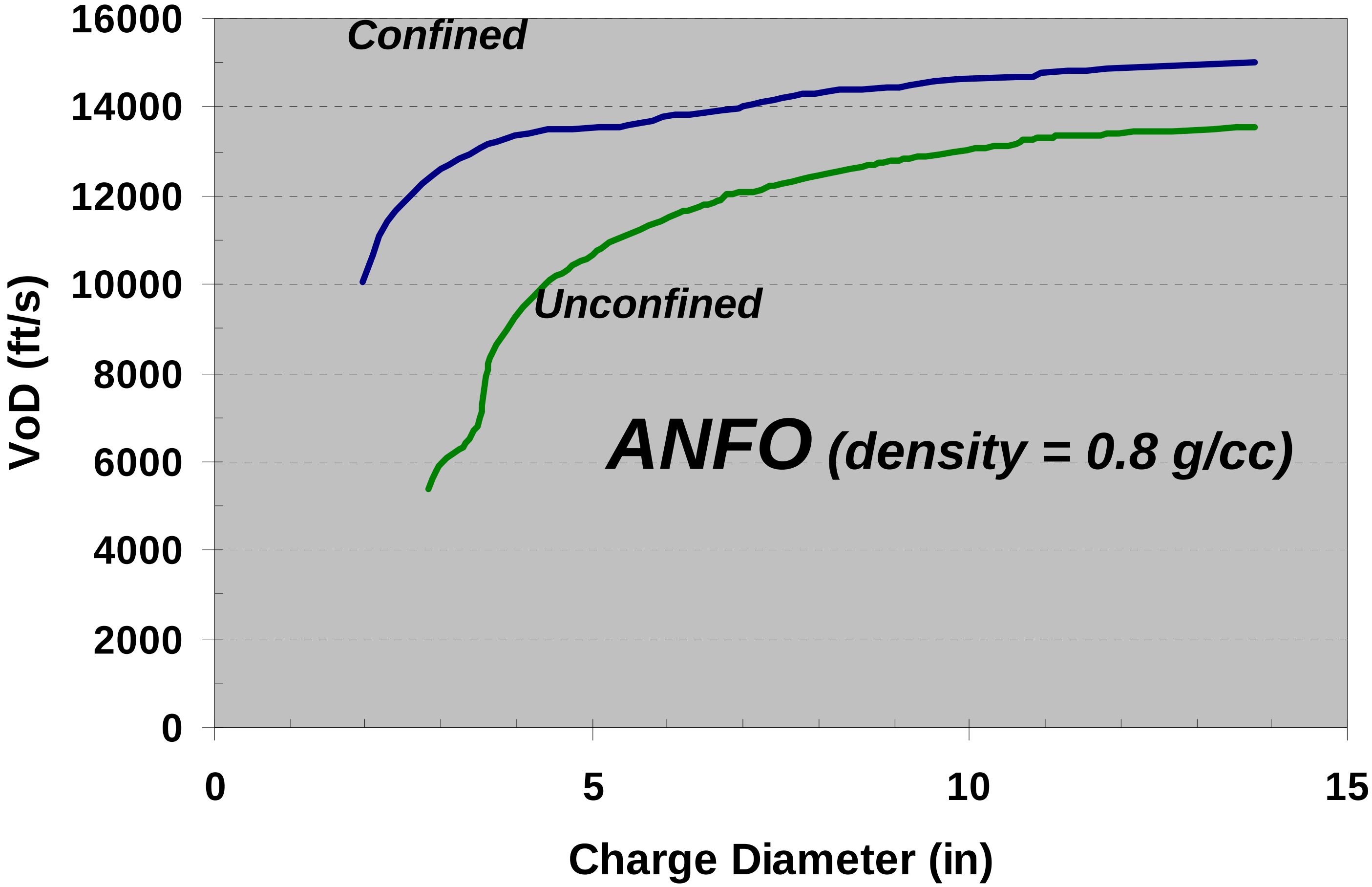
96% Ammonium Nitrate and 6% Fuel Oil.

- Physical Properties
  - ✓ Bulk poured density: 0.82 - 0.85 g/cm3 (dependent on AN source)
  - ✓ Loading density: 0.85 to +1.00 g/cm3 (dependent on: storage conditions, the method of handling and the number of times the AN used to mix or mixed ANFO is handled before actual loading, loading equipment used.)
  - ✓ Water resistance: none
- Detonation Properties
  - ✓ 1.5D Blasting Agent
  - ✓ AWS = 3.7 MJ/kg (401 Kcal/lb)
  - ✓ RWS = 100
  - ✓ RBS = 100 to 115
  - ✓ VoD = 2,500 to 4,500 m/s (8,200 to 14,700 ft/s)
  - ✓ High gas (heave) energy potential

Energy and Sensitivity variation of ANFO



Effect of Confinement on ANFO



Decision Points for Bulk ANFO

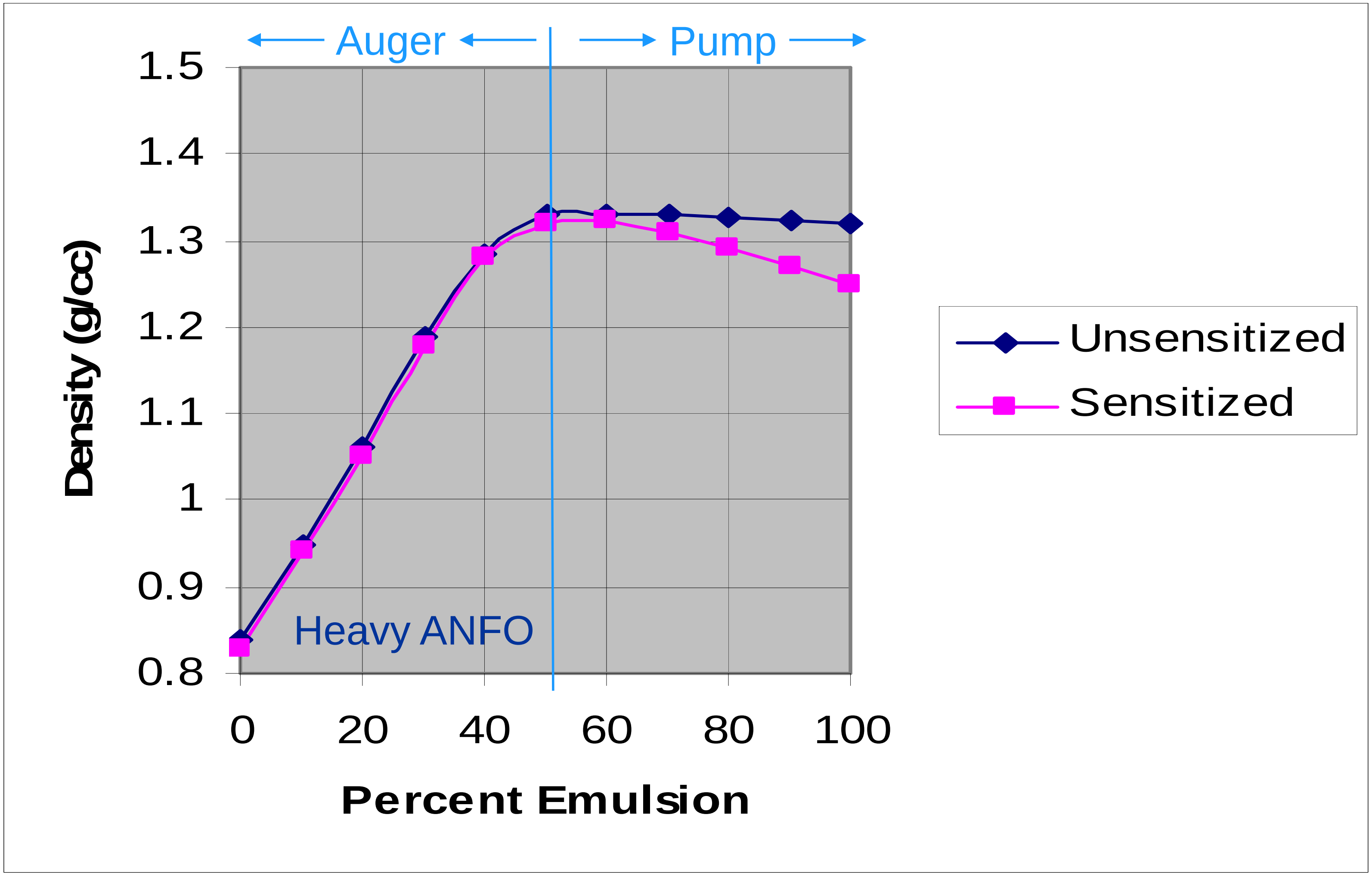
- **Advantages**
  - ✓ **Somewhat easy to manufacture correctly. Fairly simple equipment required.**
  - ✓ **Can be mixed at borehole.**
  - ✓ **Low density**
  - ✓ **High Energy**
  - ✓ **Cost effective**
- **Disadvantages**
  - ✓ **Low density**
  - ✓ **No water resistance.**
  - ✓ **Fume generation if used improperly or if under or over-fueled.**
  - ✓ **Variable Energy output if used improperly or if under or over-fueled.**
  - ✓ **Requires additional materials and equipment if water is present in holes.**
    - Liners
    - Dewatering Pumps

Heavy ANFO Blends

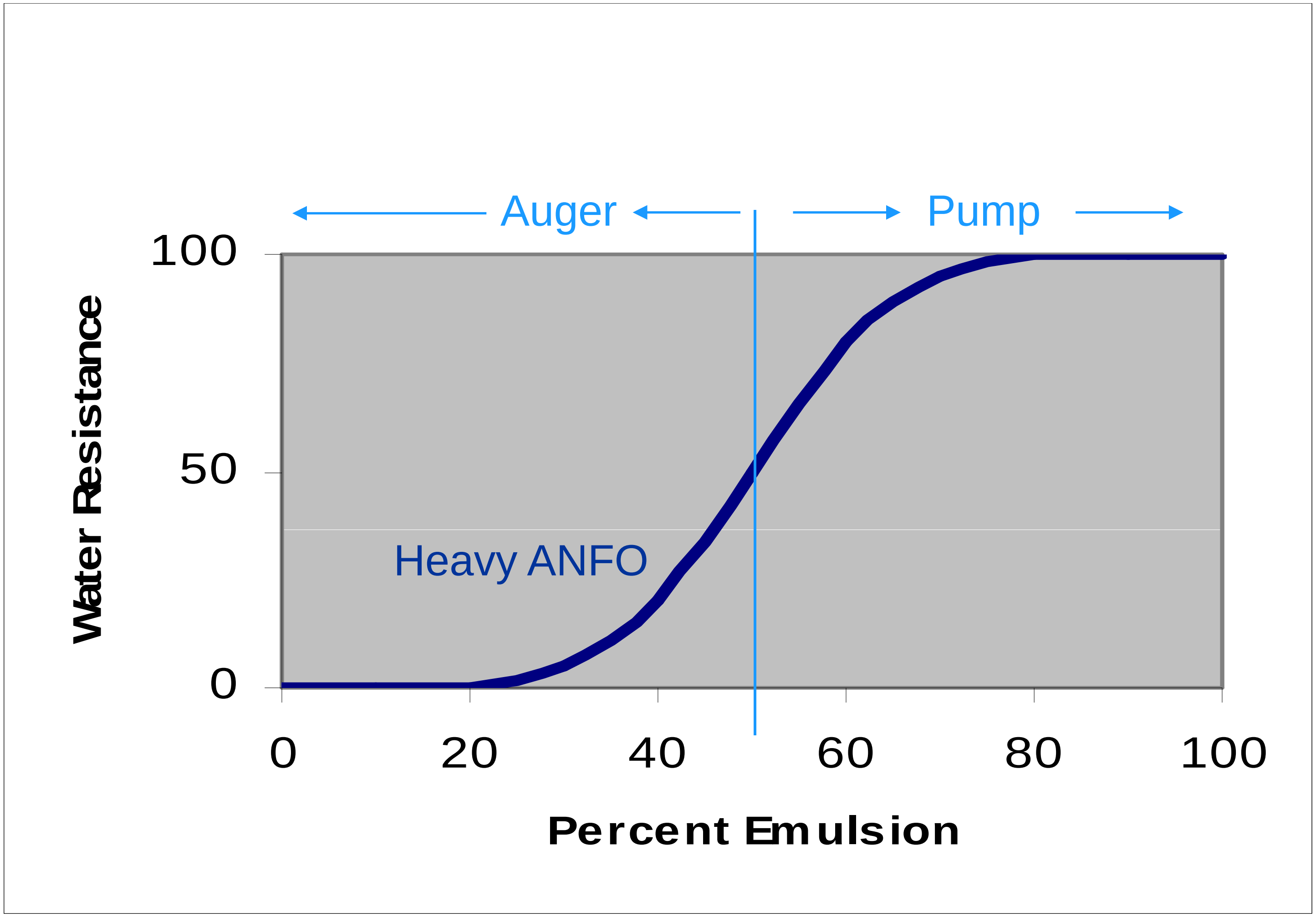
Blend of ANFO and un-sensitized water gel or emulsion matrix or ANFO and sensitized water gel or emulsion explosive matrix. (contain greater than 50% ANFO)

- **Physical Properties**
  - ✓ **Bulk density range is 0.95 to 1.35 g/cm3 (dependent of ANFO percentage in blend)**
  - ✓ **Water resistance increases with the increasing emulsion content in the blend**
  - ✓ **Higher water resistance than ANFO**
- **Detonation Properties**
  - ✓ **1.5D Blasting Agent.**
  - ✓ **Critical Diameter decreases with increasing ANFO content.**
  - ✓ **VoD increases with decreasing ANFO content. (13,800 to 17,700 ft/sec)**
  - ✓ **AWS decreases as ANFO percentage decreases in blend.**
  - ✓ **RBS increases as ANFO percentage increases in blend.**

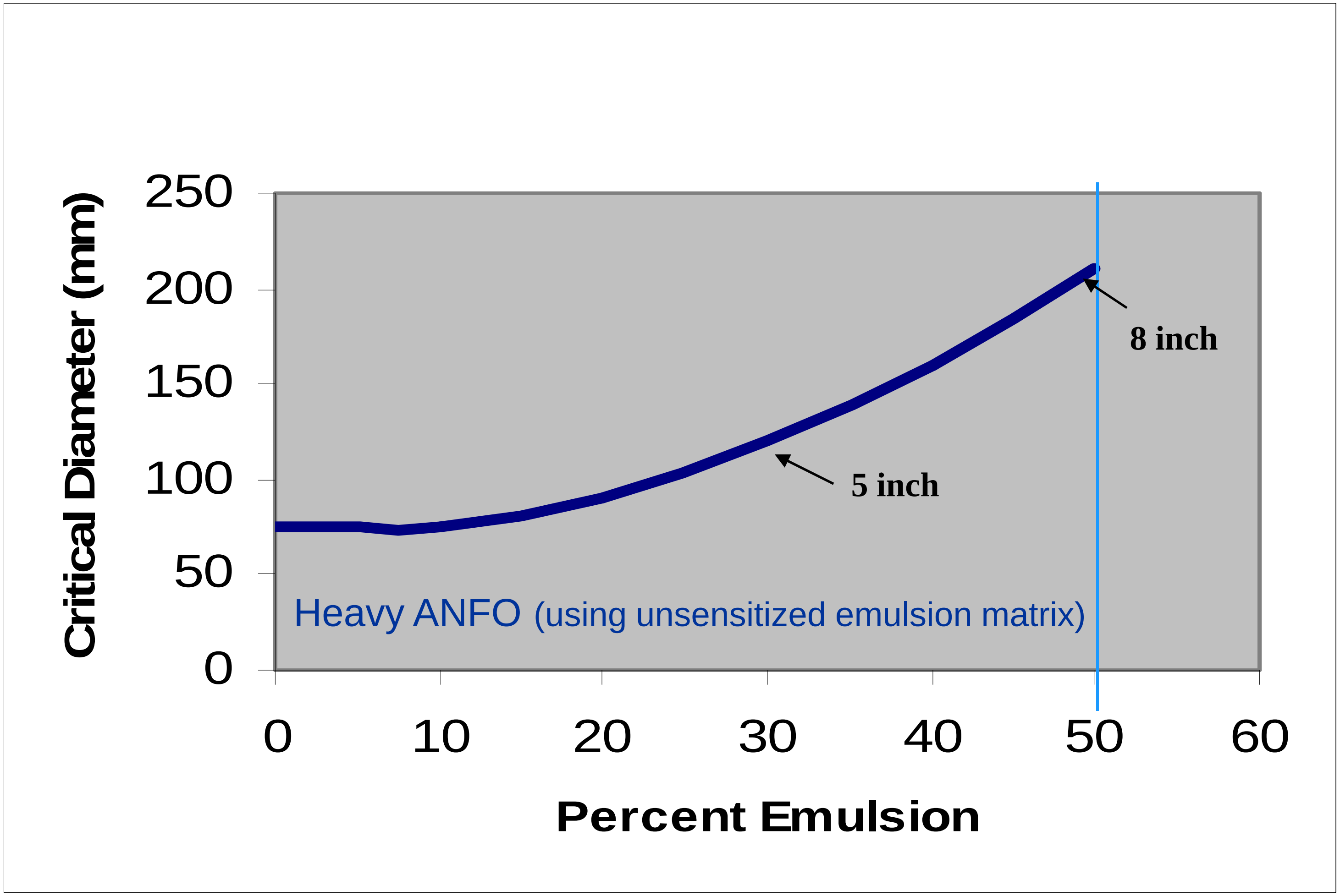
Density vs % Emulsion in Heavy ANFO



Water Resistance vs % Emulsion in Heavy ANFO



Critical Diameter vs % Emulsion in Heavy ANFO



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Decision Points for Heavy ANFO Blends

- **Advantages**
  - ✓ **Mixed at borehole**
  - ✓ **Density can be varied for application**
  - ✓ **VoD and Energy (AWS) can be varied for application**
  - ✓ **High RBS Energy**
  - ✓ **More water resistant than ANFO.**
- **Disadvantages**
  - ✓ **Must use emulsion compatible AN for ANFO used in the Heavy ANFO Blend.**
  - ✓ **Requires more specialized equipment than ANFO.**
  - ✓ **Field Quality Control is necessity. (Particularly with unsensitized matrix)**
  - ✓ **Variation in Density, Critical Diameter, VoD, and Energy if blended inconsistently.**
  - ✓ **Requires additional materials and equipment if water is present in holes.**
    - Liners
    - Dewatering Pumps

Pumpable
Bulk Emulsion ANFO Blends

Blend of water gel or emulsion explosive matrix and ANFO or field sensitized water gel or emulsion matrix and ANFO. (contain greater than 60% emulsion or water gel matrix)

- **Physical Properties**
  - ✓ **Bulk density range is 1.28 to 1.32 g/cm3 (dependent on Water gel or Emulsion matrix percentage in blend)**
  - ✓ **Water resistance increases with the increasing emulsion content in the blend**
  - ✓ **Good water resistance compared to Heavy ANFO Blends**
- **Detonation Properties**
  - ✓ **1.5D Blasting Agent.**
  - ✓ **Critical Diameter decreases with increasing water gel or emulsion matrix content.**
  - ✓ **VoD increases with increasing water gel or emulsion matrix content. (14,800 to 19,000 ft/s)**
  - ✓ **AWS increases with ANFO percentage in blend.**
  - ✓ **RBS increases with ANFO percentage in blend.**

Decision Points for Pumpable Emulsion ANFO Blends

- **Advantages**
  - ✓ Mixed at borehole
  - ✓ Density can be varied for application. (even further where field chemical sensitization is used).
  - ✓ VoD and Energy (AWS) can be varied for application
  - ✓ High RBS Energy
  - ✓ More water resistant than Heavy ANFO Blends.
  - ✓ Can be pumped directly into holes where water is present, Does not require additional materials and equipment.
- **Disadvantages**
  - ✓ Must use emulsion compatible AN for ANFO used in the Pumpable Emulsion ANFO Blend.
  - ✓ Requires more specialized equipment than Heavy ANFO Blends.
  - ✓ Field Quality Control is necessity. (Particularly with unsensitized matrix)
  - ✓ Variation in Density, Critical Diameter, VoD, and Energy if blended inconsistently

Pumpable
Bulk Emulsion Explosives

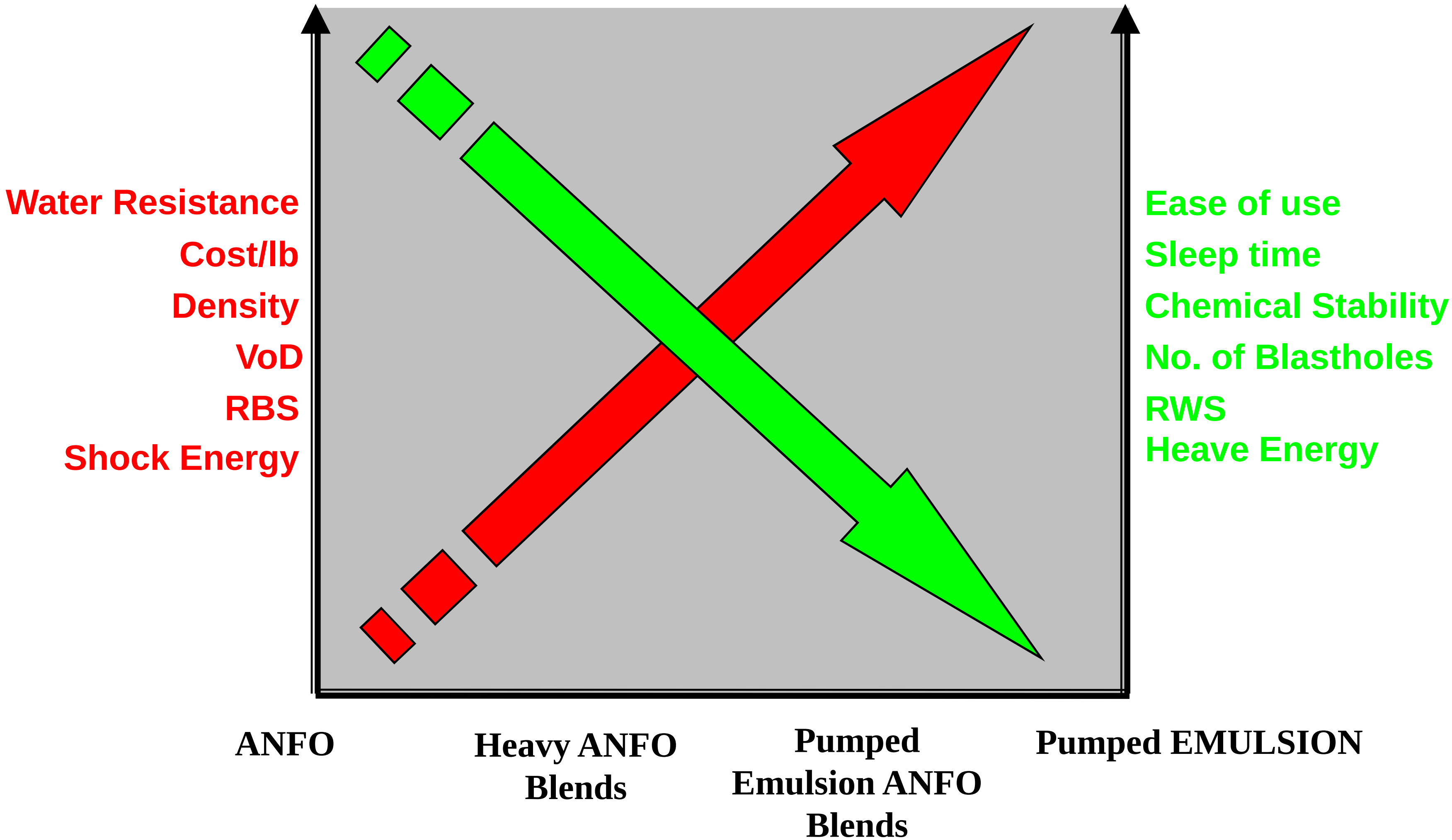
Pumpable Emulsion Explosive or field sensitized Emulsion matrix.

- **Physical Properties**
  - ✓ **Bulk density range is 1.20 to 1.35 g/cm3 (emulsion explosive)**
  - ✓ **Bulk density range is 0.85 to 1.35 g/cm3 (field sensitized emulsion matrix)**
  - ✓ **Color related to additives.**
  - ✓ **Excellent Water resistance.**
- **Detonation Properties**
  - ✓ **1.5D Blasting Agent.**
  - ✓ **Properties vary with chemical composition - can be tailor made to application.**
  - ✓ **Critical Diameter decreases with decreasing density.**
  - ✓ **VoD dependent on hole diameter & density (14,700 – 19,700 ft/s),**
  - ✓ **AWS dependent upon emulsion composition.**
  - ✓ **RBS increases with increasing density.**

Decision Points for Pumpable Emulsion Explosives

- **Advantages**
  - ✓ Can be field sensitized at borehole. (Only where chemical sensitization is available.)
  - ✓ Density can be varied for application. (Only where chemical sensitization is available.)
  - ✓ Density can be varied within individual borehole loads. (Only where loading technology is available.)
  - ✓ VoD and Energy (AWS) can be varied for application
  - ✓ Variable RBS Energy.
  - ✓ Excellent water resistance. No need for additional equipment.
  - ✓ Viscosity can be modified to increase performance, increase flow properties and reduce product migration.
- **Disadvantages**
  - ✓ Requires more specialized equipment than Heavy ANFO.
  - ✓ Field Quality Control is necessity. (Only where unsensitized matrix is used)
  - ✓ Variation in Density, Critical Diameter, VoD, and Energy where sensitized inconsistently.

Bulk Explosive – Value Decision



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Explosive Types – Main Explosive Charge

- **Package Explosive**
  - ✓ **Explosive, 1.1 D (detonator sensitive)**
    - Dynamite
    - Emulsion
    - Water Gel
  - ✓ **Blasting Agent, 1.5 D (not detonator sensitive)**
    - ANFO, ANFO WR
    - Water gel
    - Emulsion

Packaged Explosives

Includes Dynamites, Emulsion and Water Gel explosives

- **Physical Properties**
  - ✓ **Package density range**
    - Dynamites - 1.01 to 1.54 g/cm^3 (available in paper convolute or tube shells only)
    - Emulsions & Water gels - 1.05 to 1.28 g/cm^3 (available in paper convolute or tubes shells, plastic chubs or woven shot bags depending on product, grade and/ explosive classification.
  - ✓ **Good to Excellent Water resistance (depending on product type and grade)**
- **Detonation Properties**
  - ✓ **Dynamites 1.1D; Water gels and emulsions 1.1D or 1.5D depending on product type and grade.**
  - ✓ **VoD: Dynamites 5,000 to 20,000 ft/sec; Water Gels and Emulsions 13,000 to 21,000 ft/sec.**
  - ✓ **RWS: Dynamites 0.96 to 1.21 ; Water Gels & Emulsions 0.84 to 1.14**
  - ✓ **RBS: Dynamites 1.30 to 2.31 ; Water Gels & Emulsions 1.18 to 1.38**

Decision Points for Packaged Explosives

- **Advantages**
  - ✓ **Fixed configuration**
    - Maximum control of explosive weight per deck per hole
    - Maximum control of explosive load factor (lbs/ft).
  - ✓ **Dynamite provides high densities, RWS, RBS, Pressure resistance and sensitivity. It is very effective in demanding quarry applications.**
  - ✓ **Good to excellent water resistance depending on grade.**
  - ✓ **No mechanical equipment necessary for loading.**
- **Disadvantages**
  - ✓ **Labor intensive**
  - ✓ **Disposal of package materials (1.1 D only)**
  - ✓ **Packaged explosives cannot completely fill the blasthole.**
  - ✓ **Some energy is lost converting water in the blasthole to steam during the detonation, reducing available energy.**
  - ✓ **For package diameter 4 inch and larger the 1st package requires lowering onto primer in dry boreholes. Emulsion packages need to be lowered into dry boreholes deeper than 100 ft.**

Explosive Types – For use in Primer make-up

- **Package Explosive**
  - ✓ **Explosive, 1.1 D (detonator sensitive)**
    - Dynamite
    - Emulsion
    - Cast Boosters

Explosive Primer

A primer is defined as a high explosive with a detonator properly attached

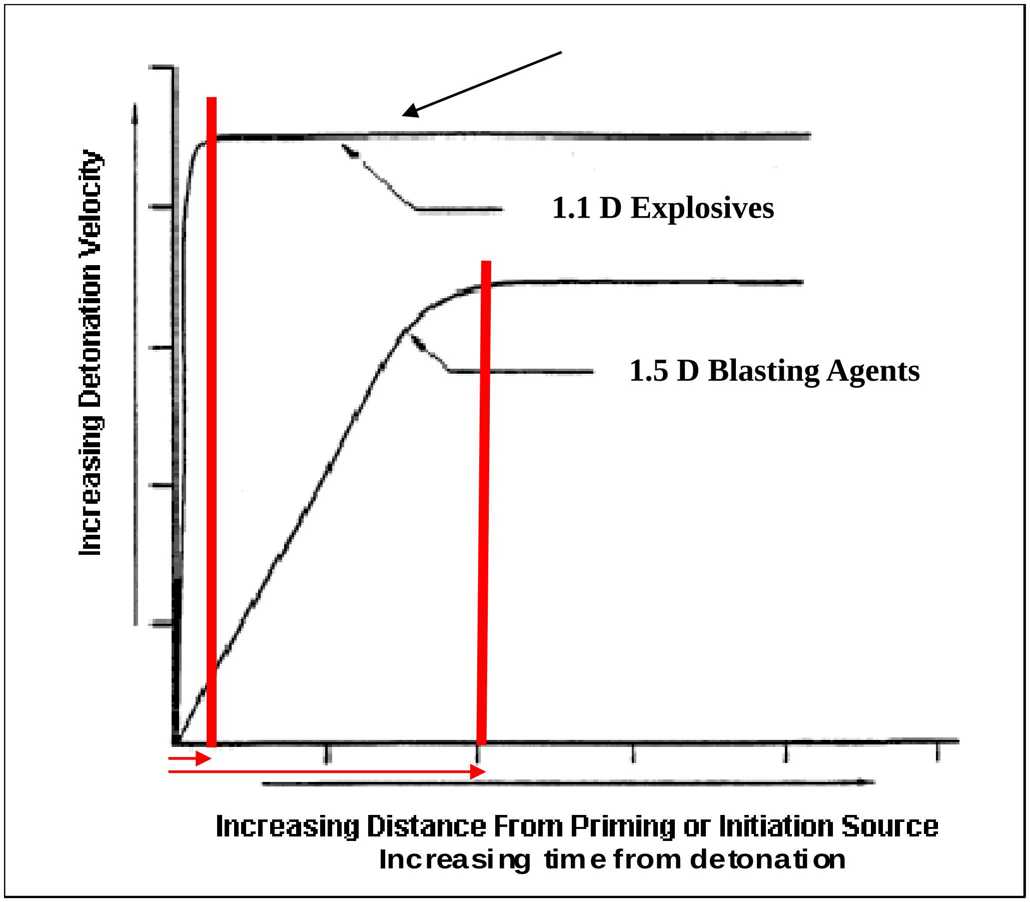
The purpose of a primer is to provide sufficient explosive energy to initiate detonation of the main explosive charge.

- The performance of the main explosive charge can be influenced by:
  - ✓ the choice of primer,
  - ✓ the number of primers used in a column,
  - ✓ the distance between the number of primers and
  - ✓ the timing of the initiation of the primers .
- Primer selection should be based on:
  - ✓ Choice of main explosive
  - ✓ Composition
  - ✓ Shape
    - Diameter that best matches the charge or hole diameter. Particularly with 1.5D Blasting Agents.

Explosive Primer

- There is a distance from the point of initiation in the explosive column, that is specific to every explosive, over which the detonation reaction travels before it reaches its steady state. This is the “Run-up” distance.
  - ✓ The “Run-up distance is reduced with increasing size and density and VoD primers
- 1.5D Blasting Agents have much longer run up distances than 1.1D Explosive materials.
- Some 1.5D Blasting Agents “Run-up” distance can extend 1 - 3 hole diameter lengths if a primer has low density and VoD or is undersized.
- Some 1.5D Blasting Agents steady state VoD can be overdriven for distances of at most 1 - 3 hole diameters if a very efficient and over sized primer is used.

“Run-up” distance and time



Initiation Systems

Baron Fidler

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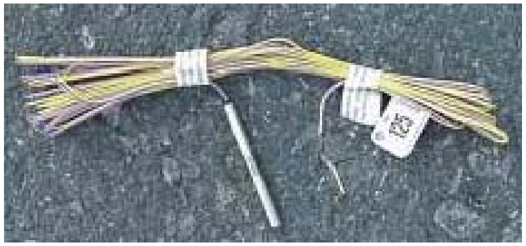
Choosing Optimum Type

- **Initiation System**
  - ✓ **Type signal**
  - ✓ **Timing options**
    - Fixed
      - Number of delay periods
    - Programmability
  - ✓ **Accuracy/Precision**
  - ✓ **Storage, Transportation and Loading/Handling**
  - ✓ **Value**

Various Types of Initiation Systems

- Detonating Cord
- Nonelectric
- Electric
- Electronic



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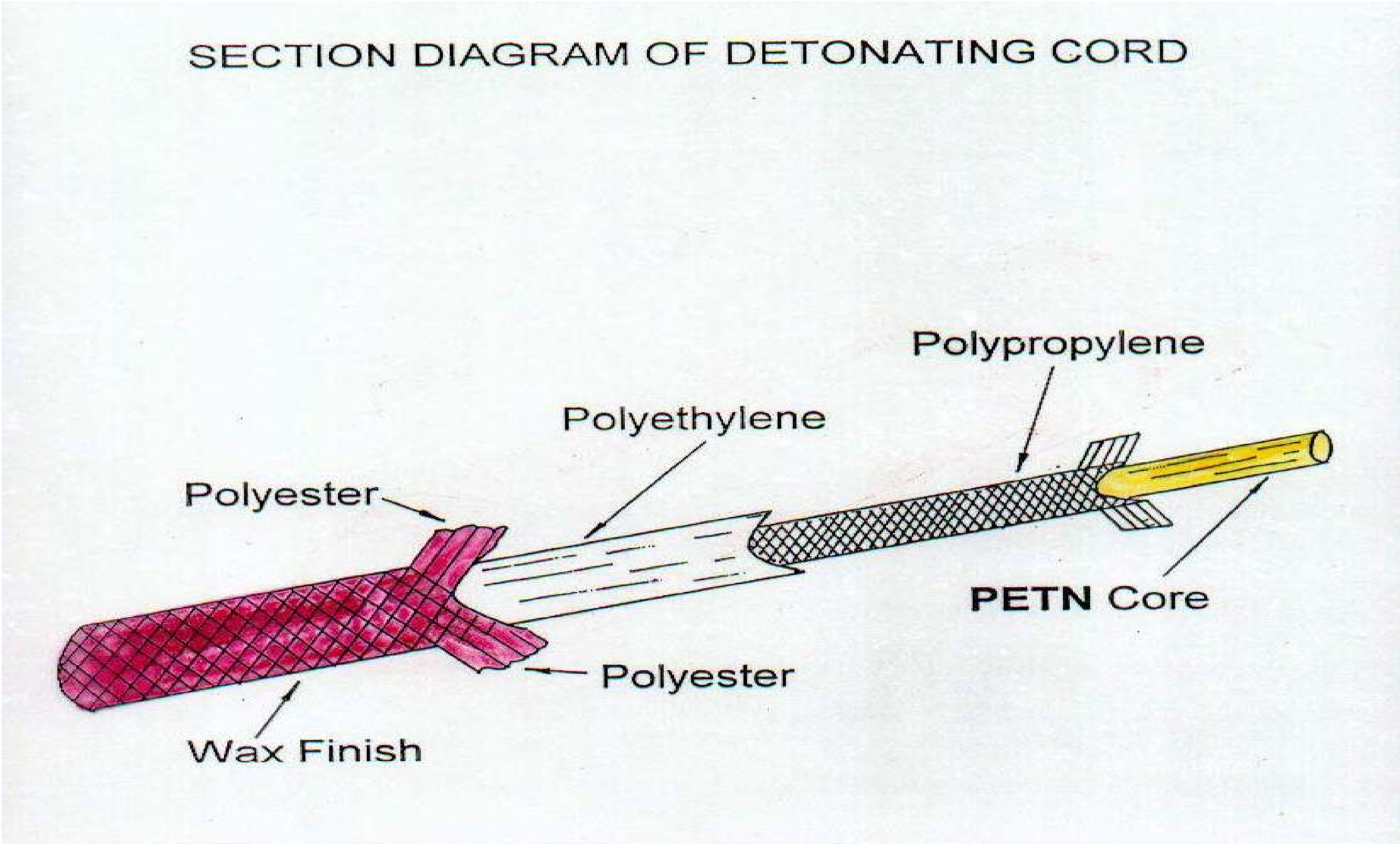
Explosive Types – Initiation System

- **Nonelectric**
  - ✓ **Miniaturized Detonating Cord / NONEL**
    - Low core load detonating cord
    - Millisecond delay period detonators – surface and in-hole
  - ✓ **NONEL**
    - Shock tube lead
    - Millisecond delay period detonators – surface and in-hole
- **Electric**
  - ✓ **Copper leg wires**
  - ✓ **Millisecond delay period detonators**
  - ✓ **Blasting Equipment**
    - Standard Capacitor Discharge Blasting Machine
    - Sequential Capacitor Discharge Blasting Machine

Detonating Cord

- **When to Choose**
  - ✓ **Extreme Loading Conditions**
  - ✓ **Multiple Priming Requirements**
  - ✓ **Closed Loop / Redundancy**
  - ✓ **Safety of Full Initiation**
    - Tunnel/Shaft
    - Cast Blasting
    - Critical Situations
  - ✓ **Contamination**
    - Salt Mines
    - Chemical Stone
    - Limestone

- **When Not to Choose**
  - ✓ **Small Diameter Blast Holes**
    - explosive damage or disruption will result
  - ✓ **Sensitive Explosive**
    - Premature initiation will result
  - ✓ **Explosive can be Desensitize**
  - ✓ **Noise Sensitive Environment**


SECTION DIAGRAM OF DETONATING CORD
Polypropylene
Polyethylene
Polyester
PETN Core
Polyester
Wax Finish

Nonelectric Initiation Systems

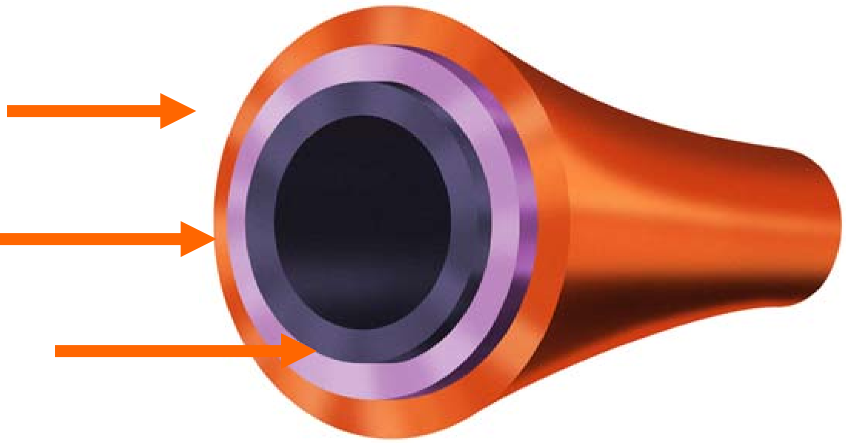
Shock tube systems

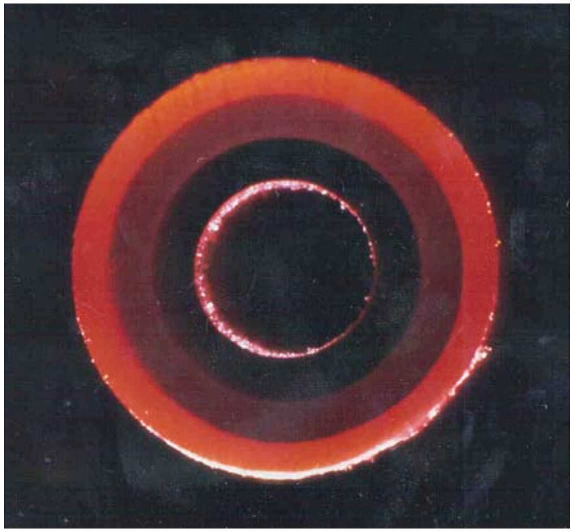
- **When to Choose**
  - ✓ **Stray Current Hazards**
  - ✓ **Static Electricity Hazards**
    - Wind
    - Low humidity
    - Plastic liners
  - ✓ **Small Diameter Holes**
  - ✓ **Timing Flexibility**
  - ✓ **Inventory Concerns**
  - ✓ **Simple Use System**

- **When Not to Choose**
  - ✓ **Extreme Loading Conditions**
  - ✓ **Mechanical or Electrical Check is a Must**
  - ✓ **Matting or Covering a Blast**

Nonelectic Shock Tube

- **External layer** for abrasion resistance and UV protection
- **Middle layer** for tensile strength, elongation and chemical resistance
- **Inner Layer** reliably holds the reactive mixture in place





Shock tube has a small diameter 3 layer plastic tube internally coated with one pound of reactive material per 100,000 feet. This tube transmits a low energy signal form the point of initiation to the delay cap at approximately 2.100 m/second (6,500 ft/sec). The detonation is sustained by such a small quantity of reactive material that the outer surface of the tube remains intact during functioning.

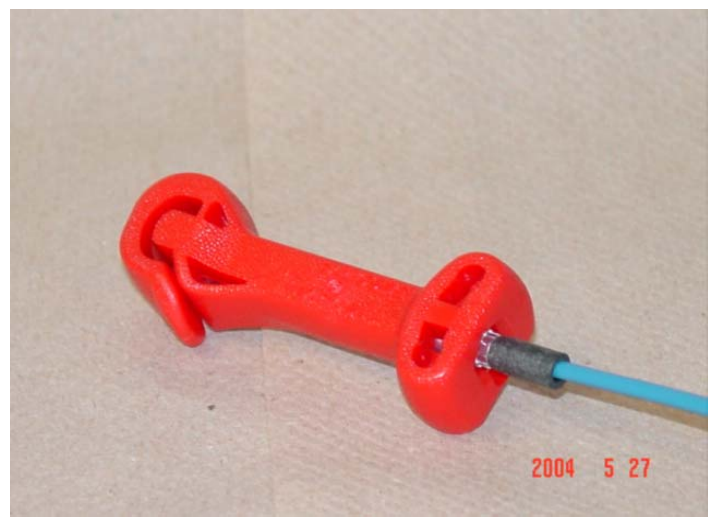
Various Packaging, similar function & application.

Surface Connectors

- **Makes hole-to-hole connections.**
  - ✓ **Sequences the shot**
  - ✓ **Hole-to-hole timing**
- **Low energy detonator.**
  - ✓ **Combined with plastic connector body reduces shrapnel hazard**
- **Multiple shock tube capacity.**
- **Contains a detonator**
  - ✓ Use caution when vehicles are "on the shot".

Connector Block Comparison

- **Always check with your manufacturer.**
  - ✓ **Different types of connectors have different tube capacities.**
  - ✓ **Some connectors require covering to prevent shrapnel.**



Product Selection

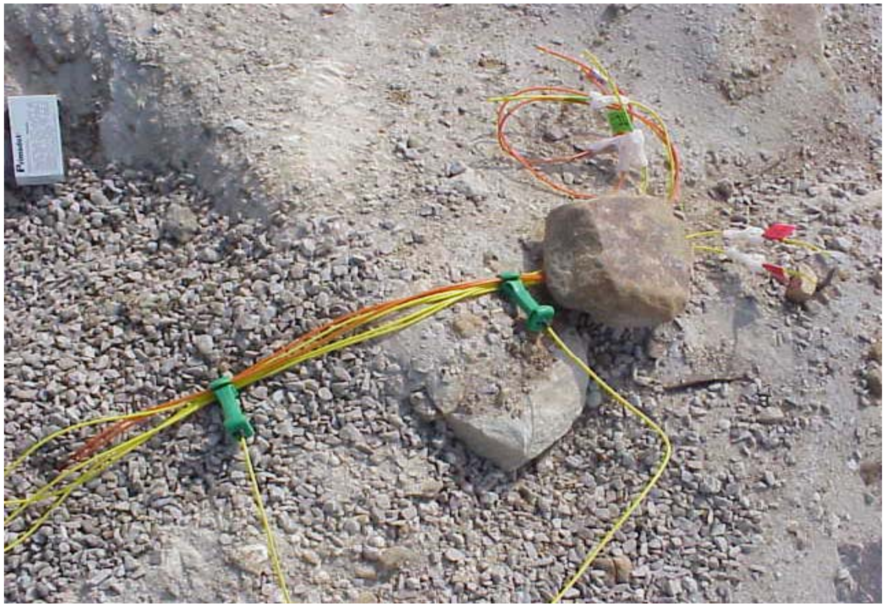
Double Ended Delay Detonators

MS Units & Surface Delays

System Advantages

- **Double Ended Delay Dets**
  - ✓ **Simplicity**
    - General purpose system
    - Well suited for most blasting applications.
  - ✓ **Reduced product inventory.**
  - ✓ **Versatility**
    - Solid column / decking
  - ✓ **Sequential**
- **MS & Surface Delays**
  - ✓ **Greater timing flexibility**
    - Not locked into 25ms
  - ✓ **Echelon hook-ups**
    - 2 & 3 row quarry shots
  - ✓ **Ideal for decking**
    - Fewer connections
    - Timing flexibility
  - ✓ **Sequential**

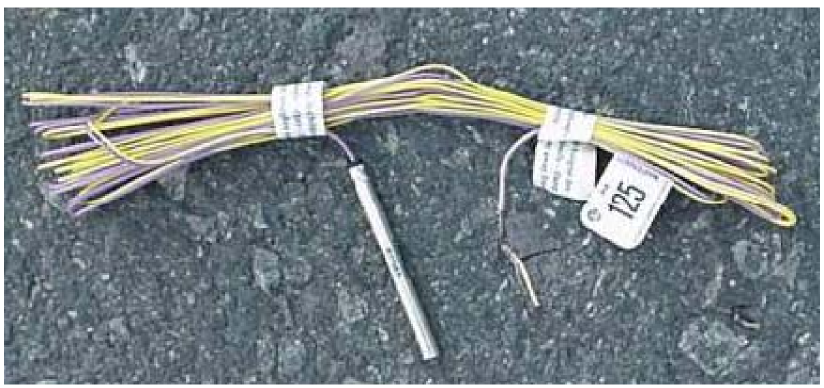
Redundant Surface Delays



- Backup surface delays provide two paths of initiation for each hole.
- Guards against the hazards associated misfired shots.
- Redundancy improves delay timing accuracy.
- Always check the surface connections.

Electric Initiation Systems

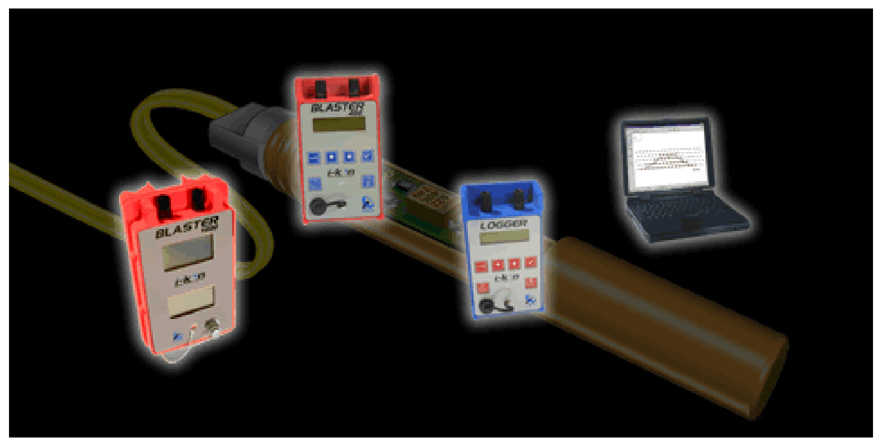
- **When to Choose**
  - ✓ **Circuit Testing Required**
  - ✓ **Matting or Covering Blasts**
  - ✓ **Contamination Concern**
    - Shock tube in Muck
    - Easy to Recycle



- **When Not to Choose**
  - ✓ **Stray Current Potential**
  - ✓ **Static Electricity hazards**
  - ✓ **Radio Frequency Hazards**

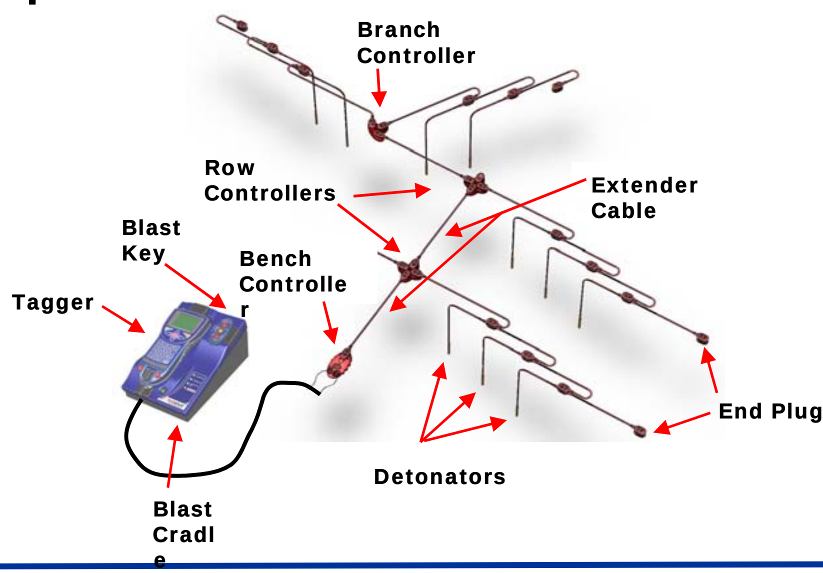
Electronic Initiation Systems

A variety of systems are available.

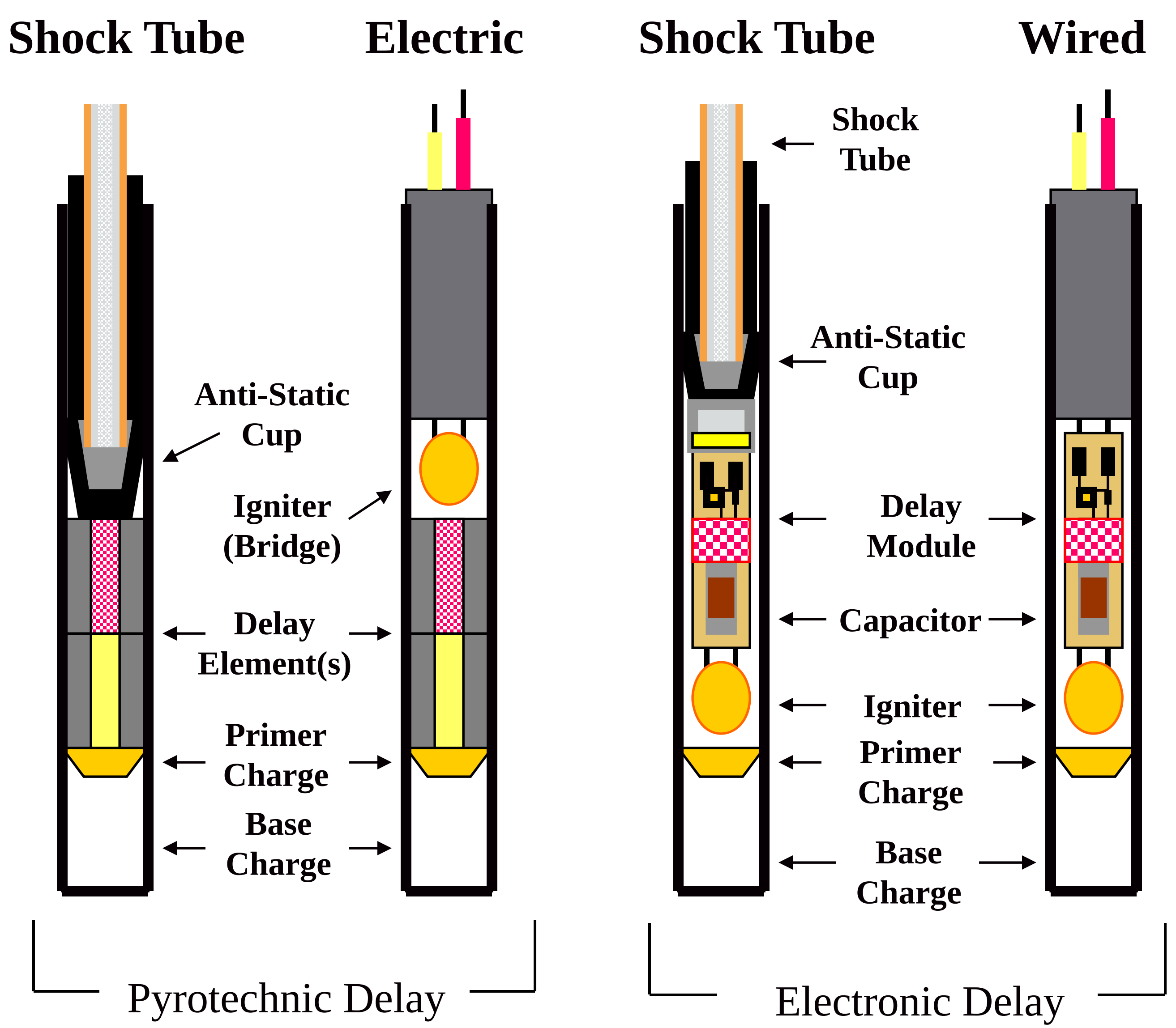


Explosive Types – Initiation System

- **Electronic**
  - ✓ **Copper leg wires**
  - ✓ **Field programmable precision delay detonators**
  - ✓ **Nonexplosive accessories**
    - Wire, connectors, controllers etc
  - ✓ **Computer testing, programming and blasting equipment.**



Generic Detonator Construction



System Understanding is Essential

- **Each manufactures system is different.**
  - ✓ **Programmable systems rely on direct communication with detonators through handheld loggers & blasting machines.**
    - Blasting machines & loggers are different.
    - Each have unique communication protocols & firing codes.
  - ✓ **Detonator construction varies.**
    - All have stored energy source to power unique timing and firing circuits.

Understanding Electronic Detonators

- Handheld test & programming units check detonator circuitry prior to final hook-up.
- The blasting machine does the final system level continuity check and detonates the shot.
- Some detonators have multiple integrated circuits and capacitors built into the "electronics package".
- Detonators may have specific operational pressure and temperature ranges.
  - ✓ **The delay package must be able to "survive the shot".**
- Wire style, connectors and hook-up will vary.

The Challenges of Electronic Systems

- Added Complexity
- Training Requirements
  - ✓ Blaster certification required for many systems.
- Environmental Limitations
  - ✓ Temperature, transient pressures & shock.
- System Cost
- Equipment
  - ✓ Must work in a rugged environment. Must be maintained.
- Dumb Intelligence
  - ✓ Program precisely the wrong timing.

Opportunities of Electronic Systems

- Added Blast Control & Improved Flexibility
  - ✓ Electronics give blasters the ability program shots with precise and accurate delay times.
  - ✓ Combined with frequency waveform analysis electronics can reduce peak particle velocities and increase frequencies.
- Improved Economics
  - ✓ Reduced production costs can be achieved through improved fragmentation & pattern expansion.
- Education of Blasters
  - ✓ Attention to all blast design parameters is required to achieve the maximum results from electronics.
- Communication with the System
  - ✓ Blast design & system interrogation
- Information/Control

Electronic Challenges / Opportunities

- Added Complexity
- Training Requirements
- Environmental Limits
  - ✓ Temp/Pressure/Shock
- Multiple User Interfaces
- Dumb Intelligence
- System Costs
- Communication
- Equipment

- **Added blast Control**
- **Education of Blasters**
- **Understand Dynamics**
  - ✓ **Better Control**
  - ✓ **More Accurate Timing**
- **Improved Flexibility**
- **Improved Economics**
- **Communication with the System**
- **Information/Control**

Electronic Initiation Systems

- **Choose the Right System**
  - ✓ **Field Programmable or Factory Programmed**
  - ✓ **Precision and Accuracy**
  - ✓ **Security Level**
  - ✓ **Blast Management Capability**
  - ✓ **Complexity**
  - ✓ **Training**
  - ✓ **Investment**

What questions do you have?

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