Explosives & Initiation systems

Harald Bornebroek

QUARRY ACADEMY

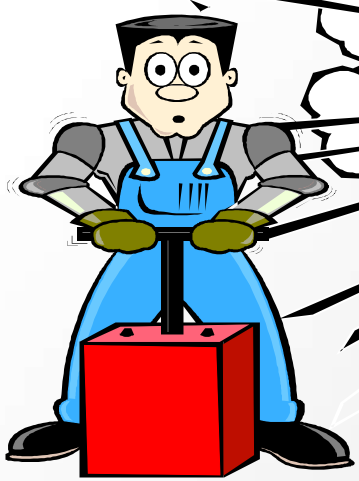
Improving Processes. Instilling Expertise.

ORICA VOLVO SANDVIK

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, 1500 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.

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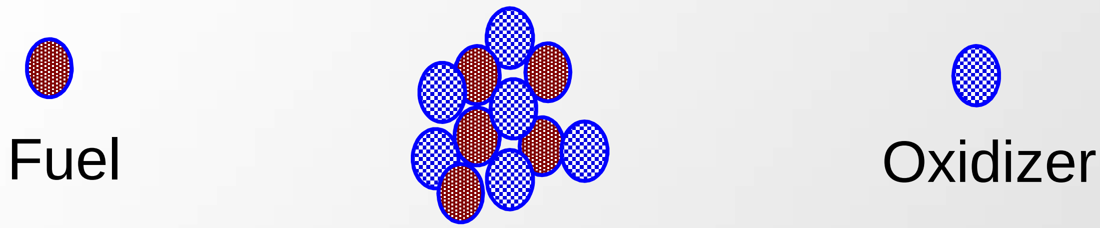
All Explosives Composed of -

- Oxidizer

- Fuel

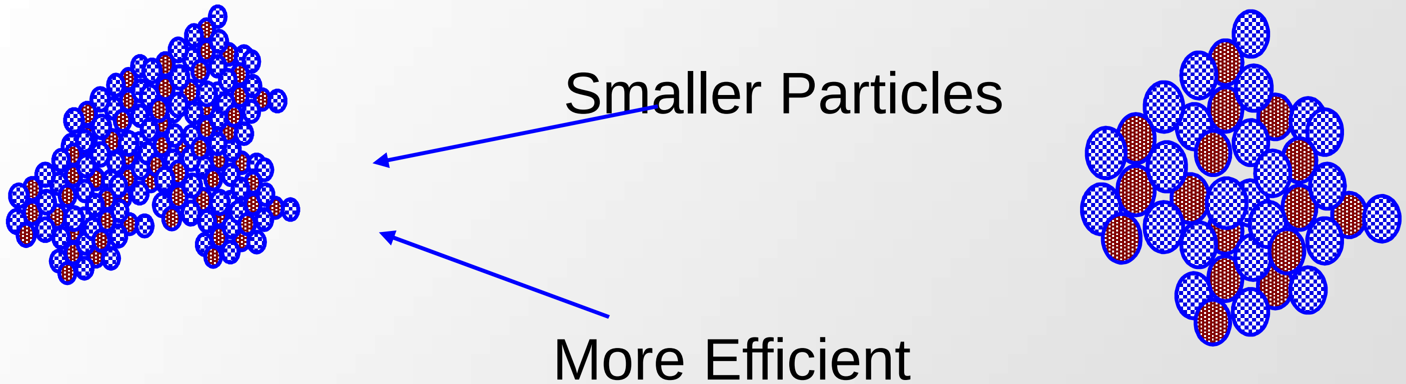
Explosive Properties



All Explosives Require Fuel and Oxidizer

Explosive Properties

Explosive efficiency is dependent on intimacy of fuel/oxidizer contact...



Emulsion Matrix

“internal“ Phase

Oxygen

Ammoniumnitrate solution
ca. 91 to 95%

“external“ Phase

Fuel

Oil & Emulsifier
ca. 5 to 9%

+ Energy

= Emulsion (Emulsionsmatrix - EP)

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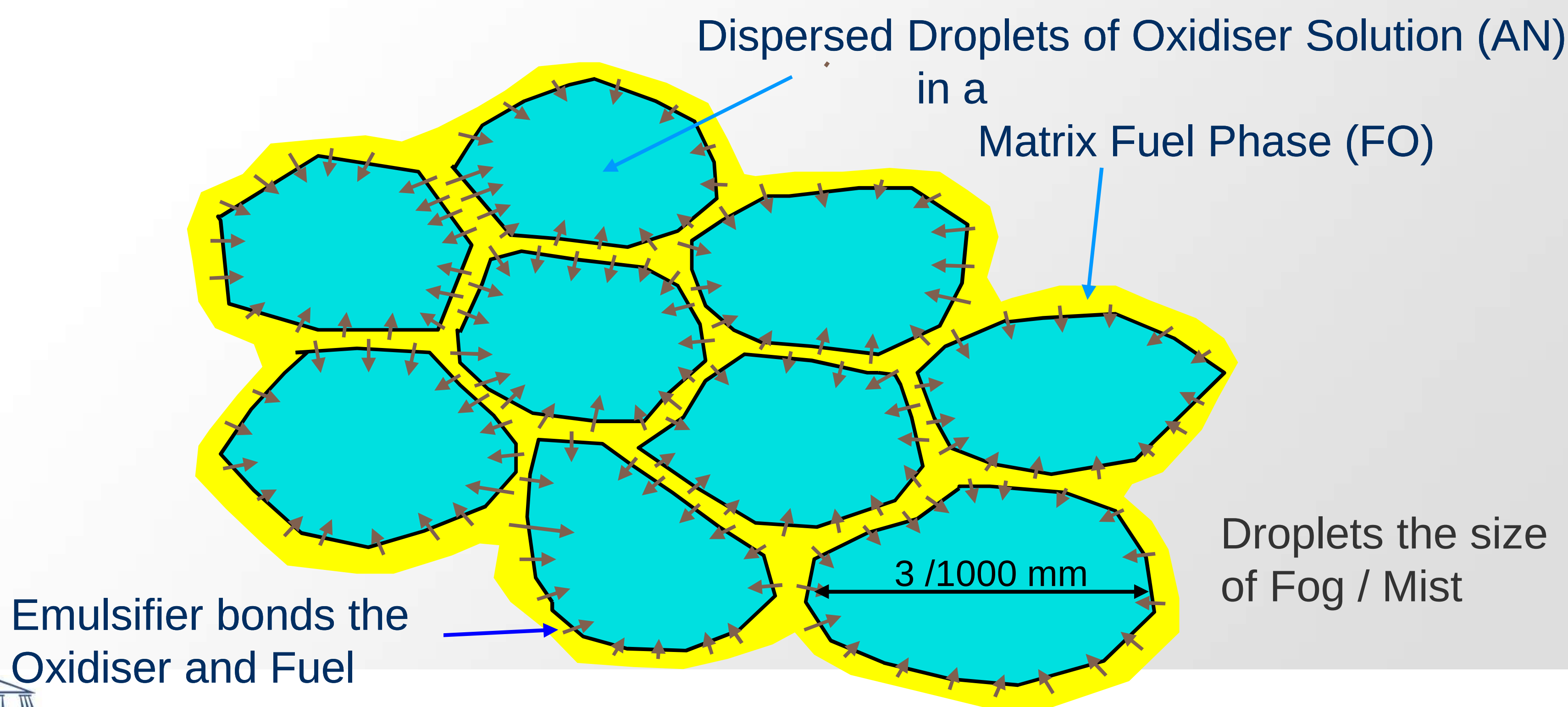
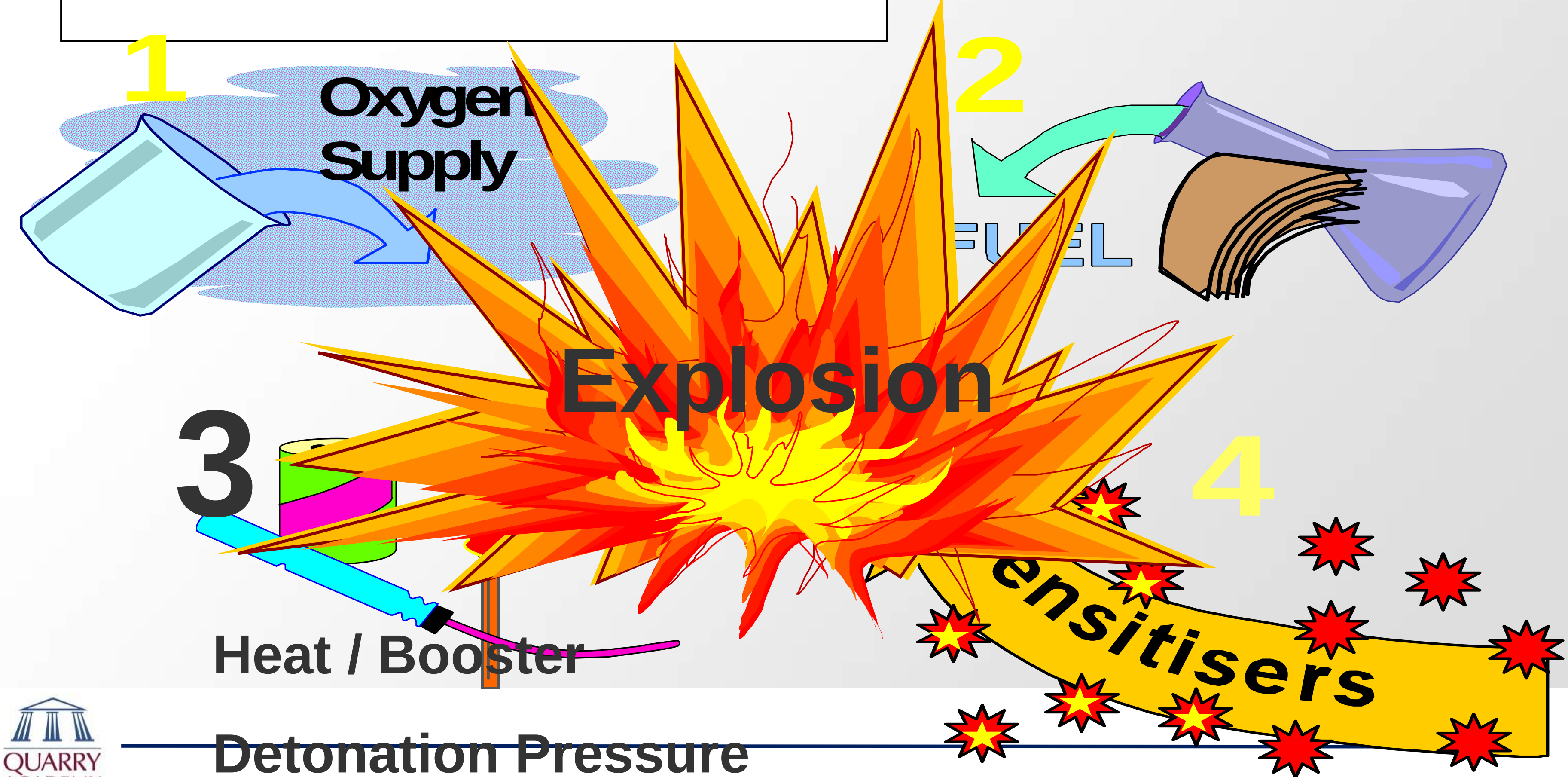
Emulsion Matrix



EXPLOSION PROCESS



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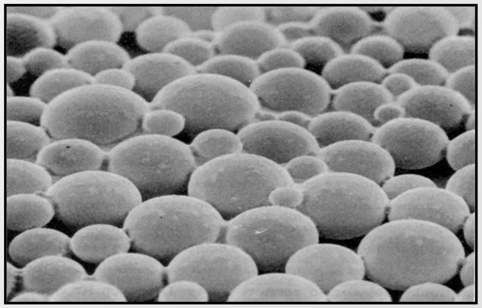
Sensitising

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



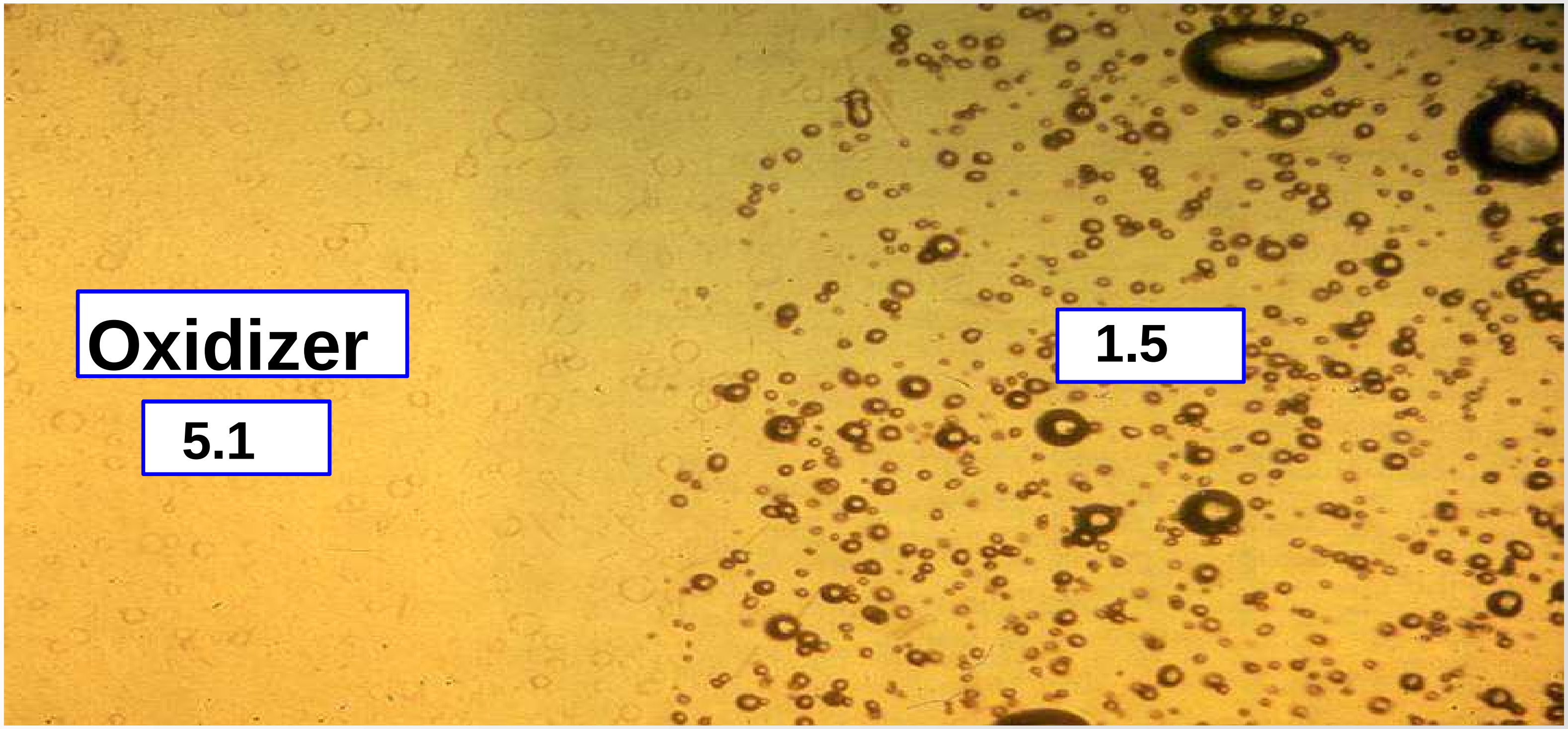
Physical sensitisation

- **Glass Micro Ballons (GMB)**

Chemical sensitisation

- **Gas bubbles ("Chemical-Gassing")**

Unsensitised Matrix   Sensitized Matrix



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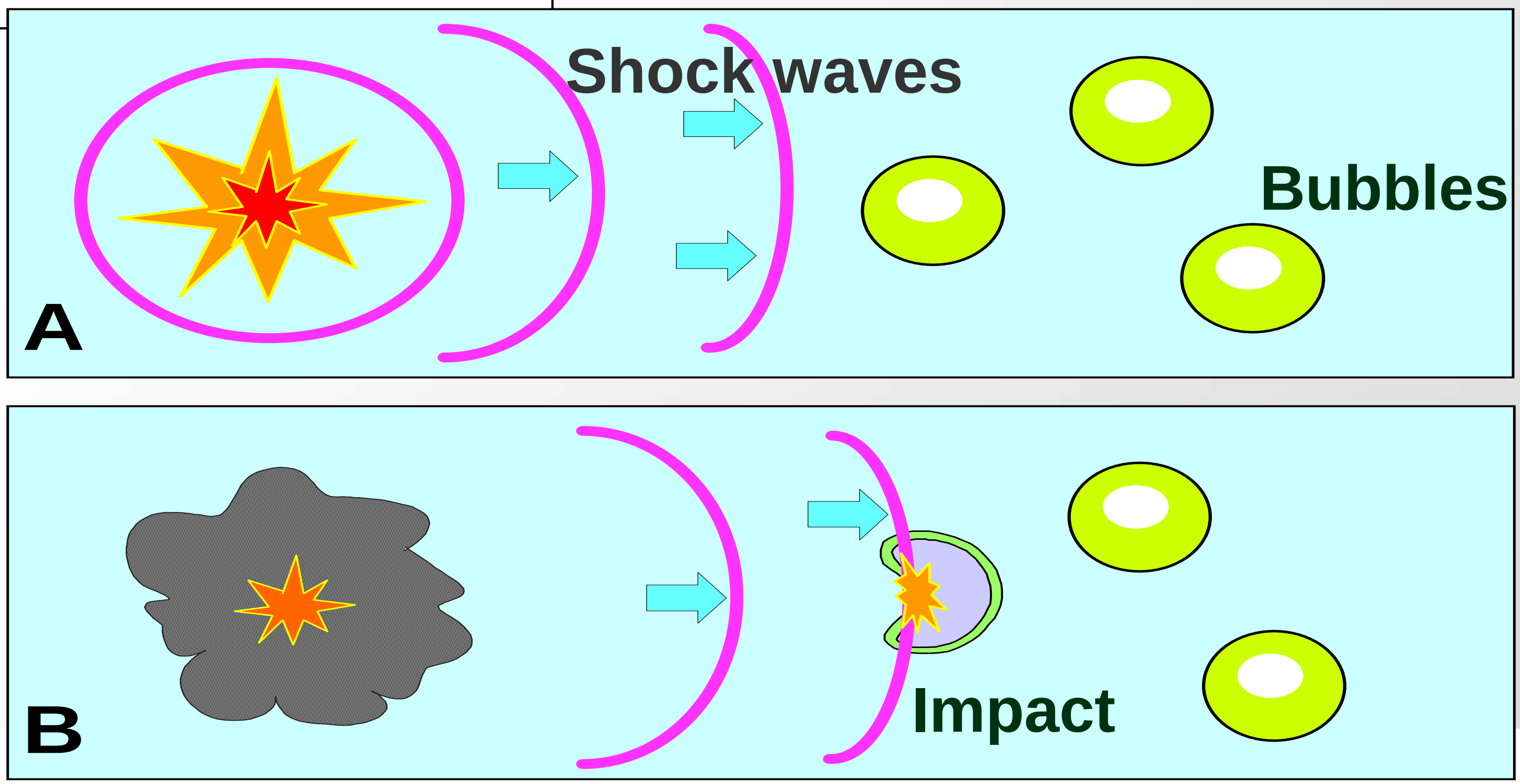
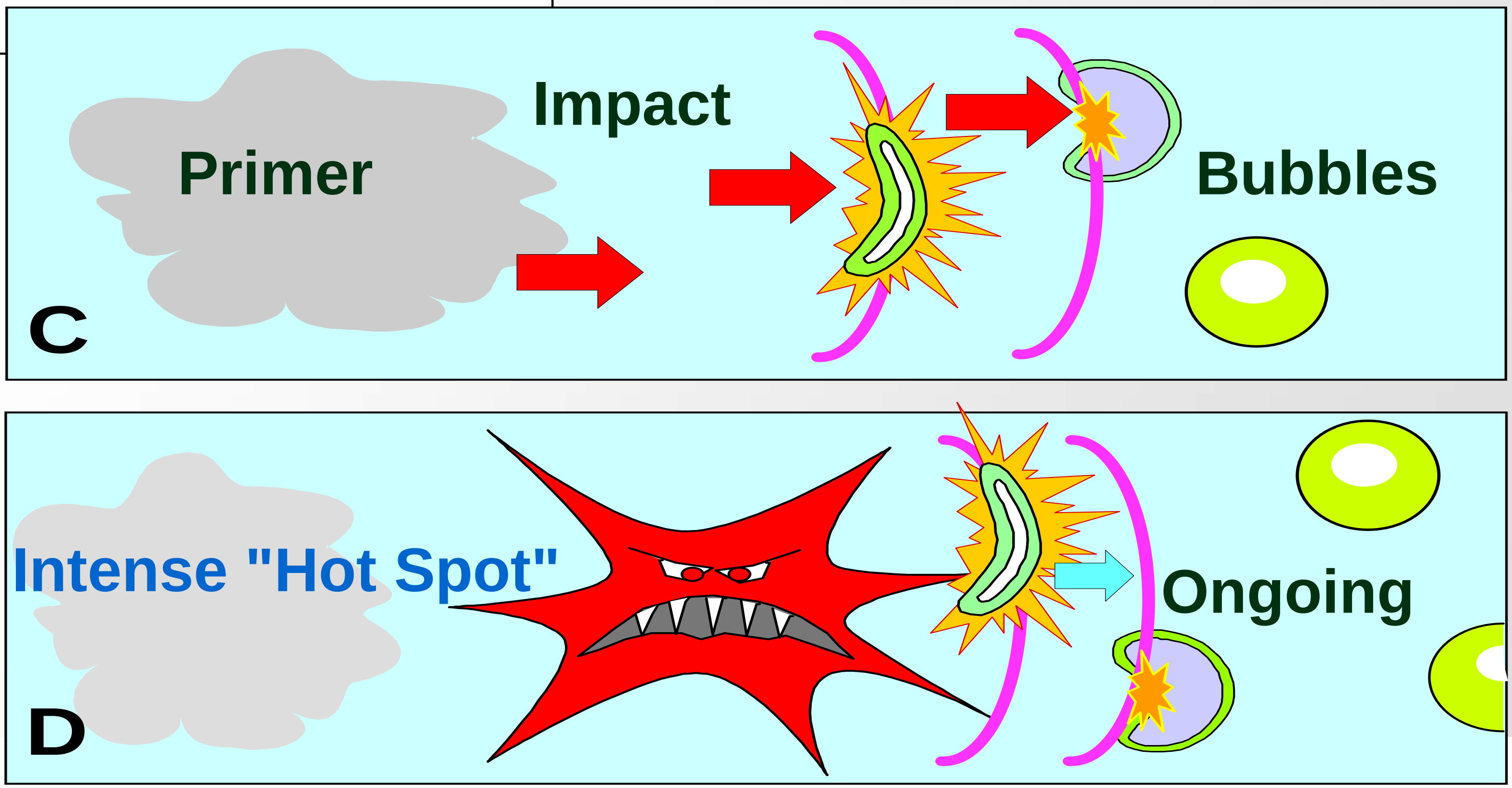
"HOT SPOTS"



QUARRY ACADEMY

"HOT SPOTS"



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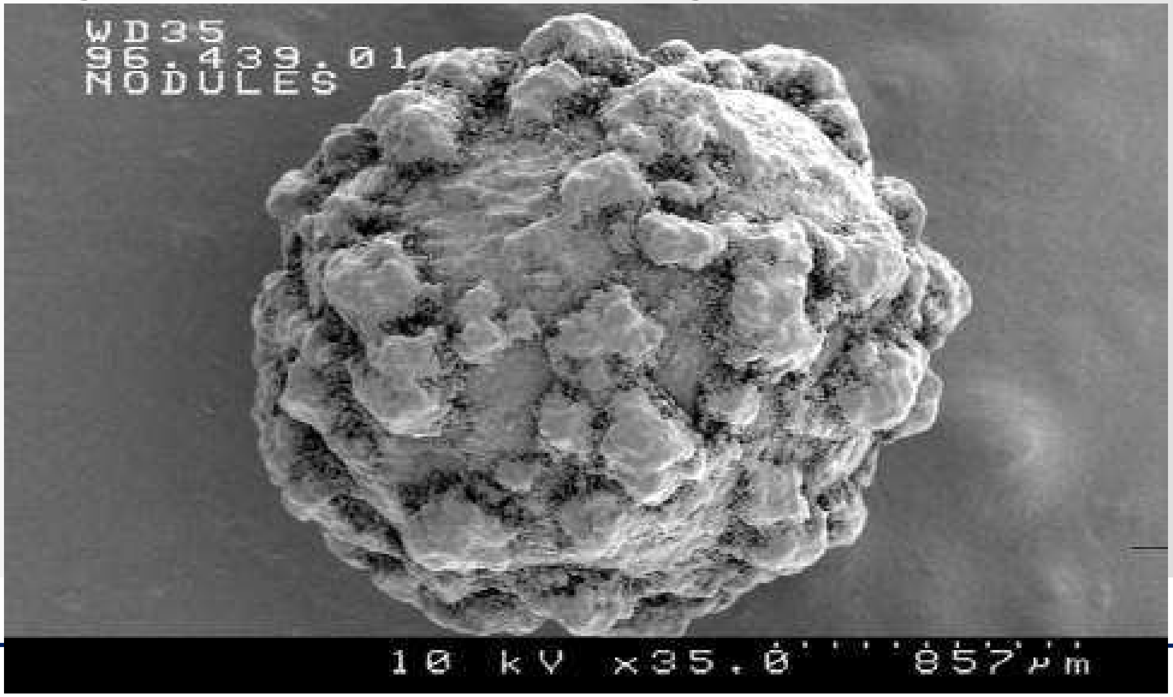
Molecular Explosives

Oxygen and Fuel In Molecule,
not just mechanically mixed

PETN
TNT
HMX



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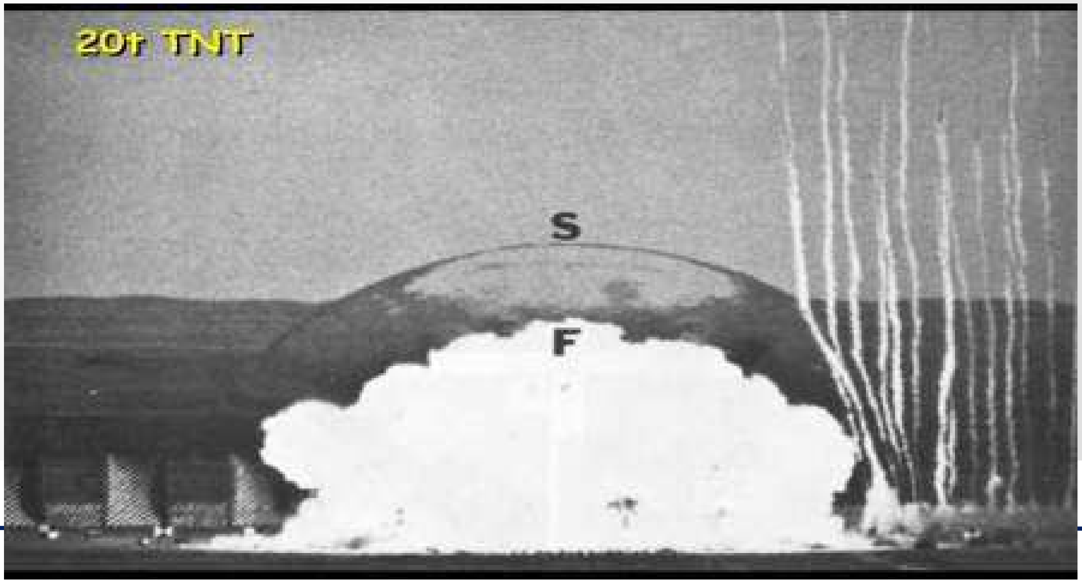
Detonation

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



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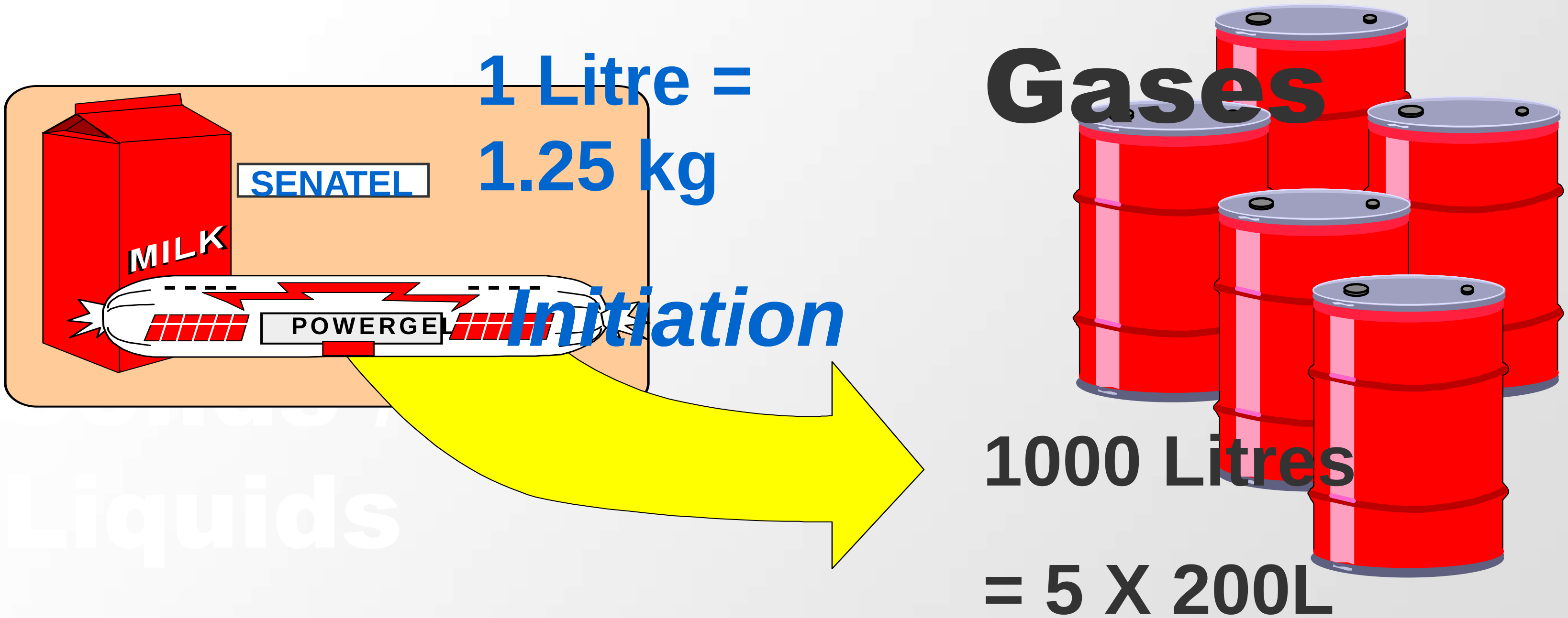
DETONATION PROCESS



1 Litre = 1.25 kg

Liquids

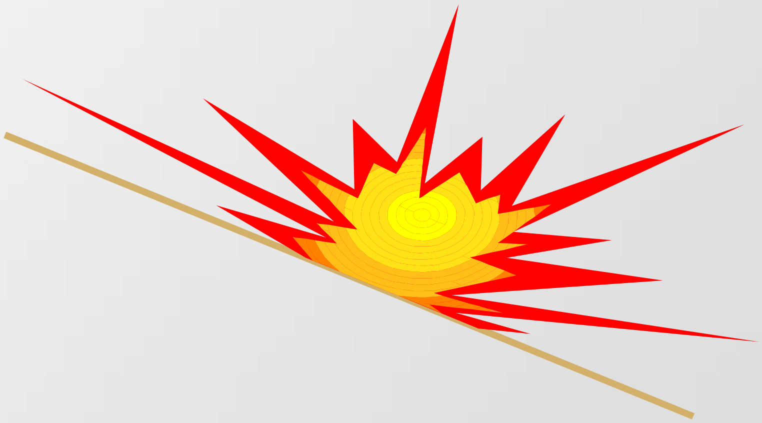
Initiation

Gases

1000 Litres

= 5 X 200L

Important Characteristics of a Detonation

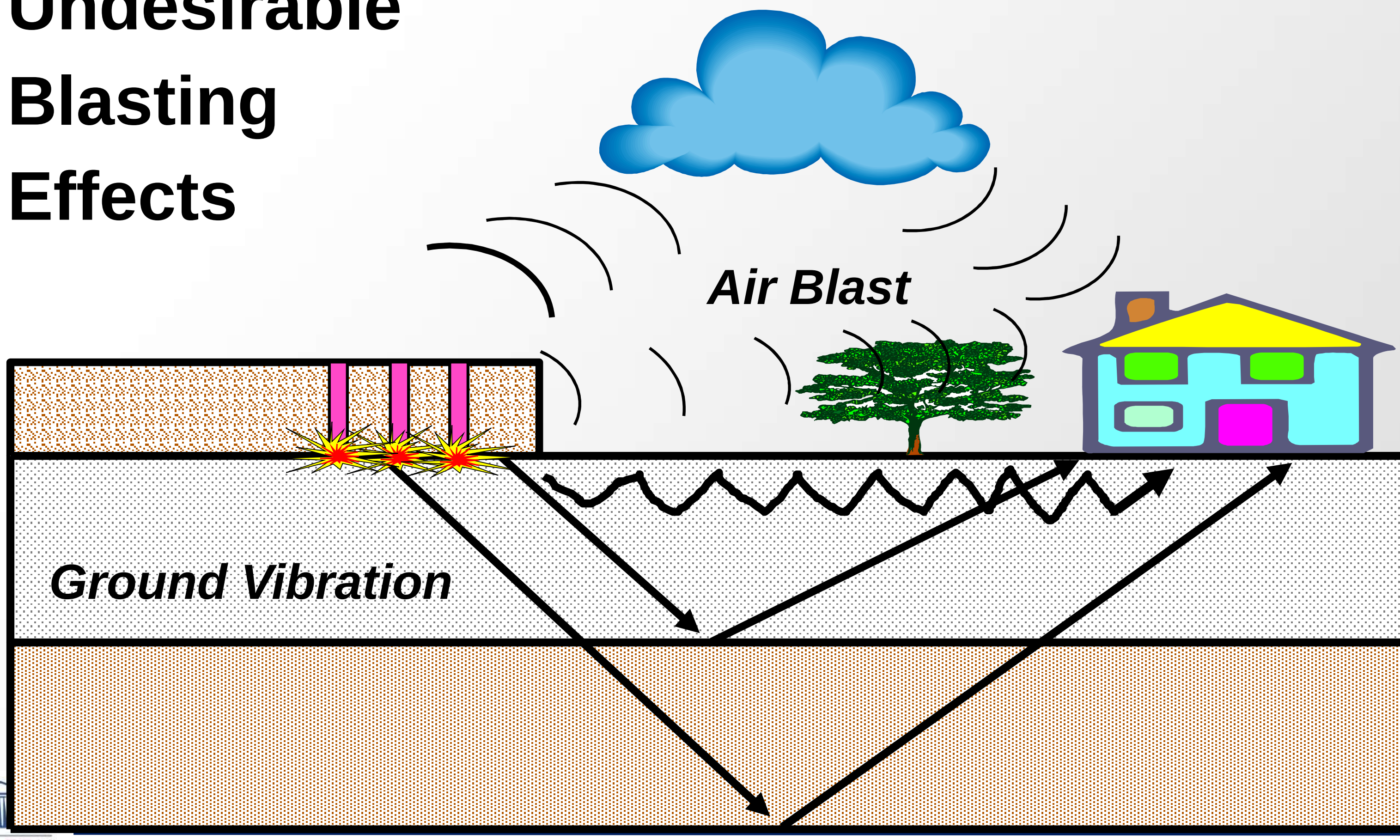


- Fast Release of Energy
- Generates Shock Wave
- Generates Large Gas Pressure

Blast Resultants

Crushing Around the Borehole Wall:	%
Crack Formation:	%
Shearing:	
Heat and Light:	%
Mass Movement:	%
Ground Movement:	%
Air Blast:	%
Total:	100 %

Undesirable Blasting Effects



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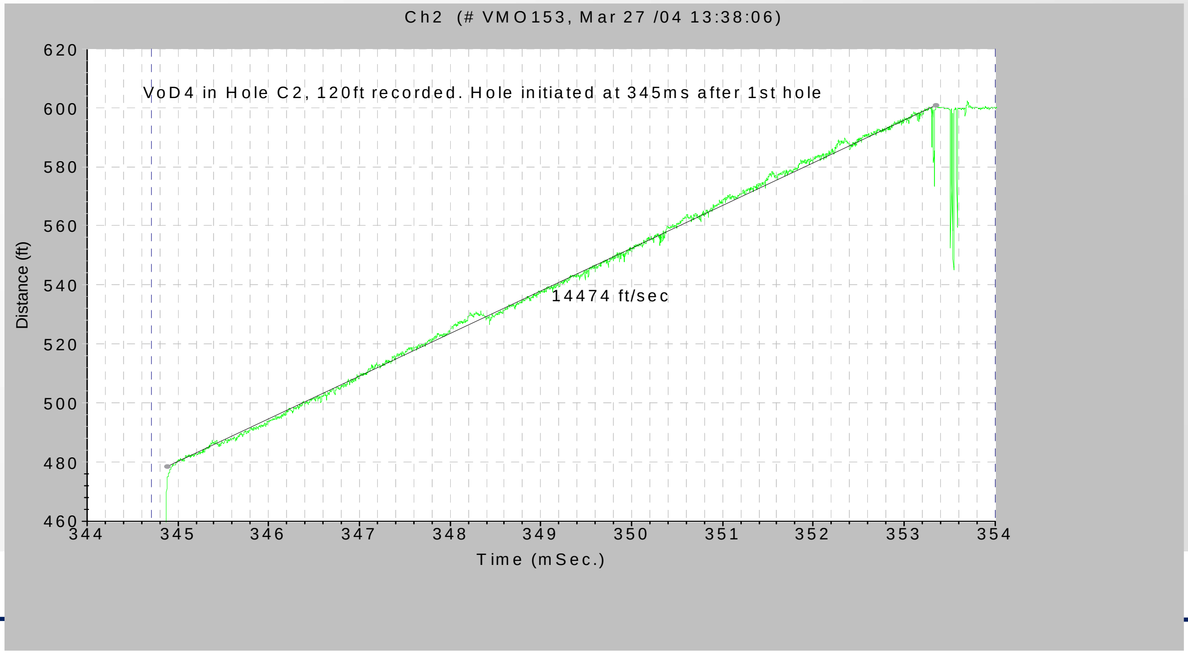
Explosive Properties

- 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



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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 $(VOD)^2$

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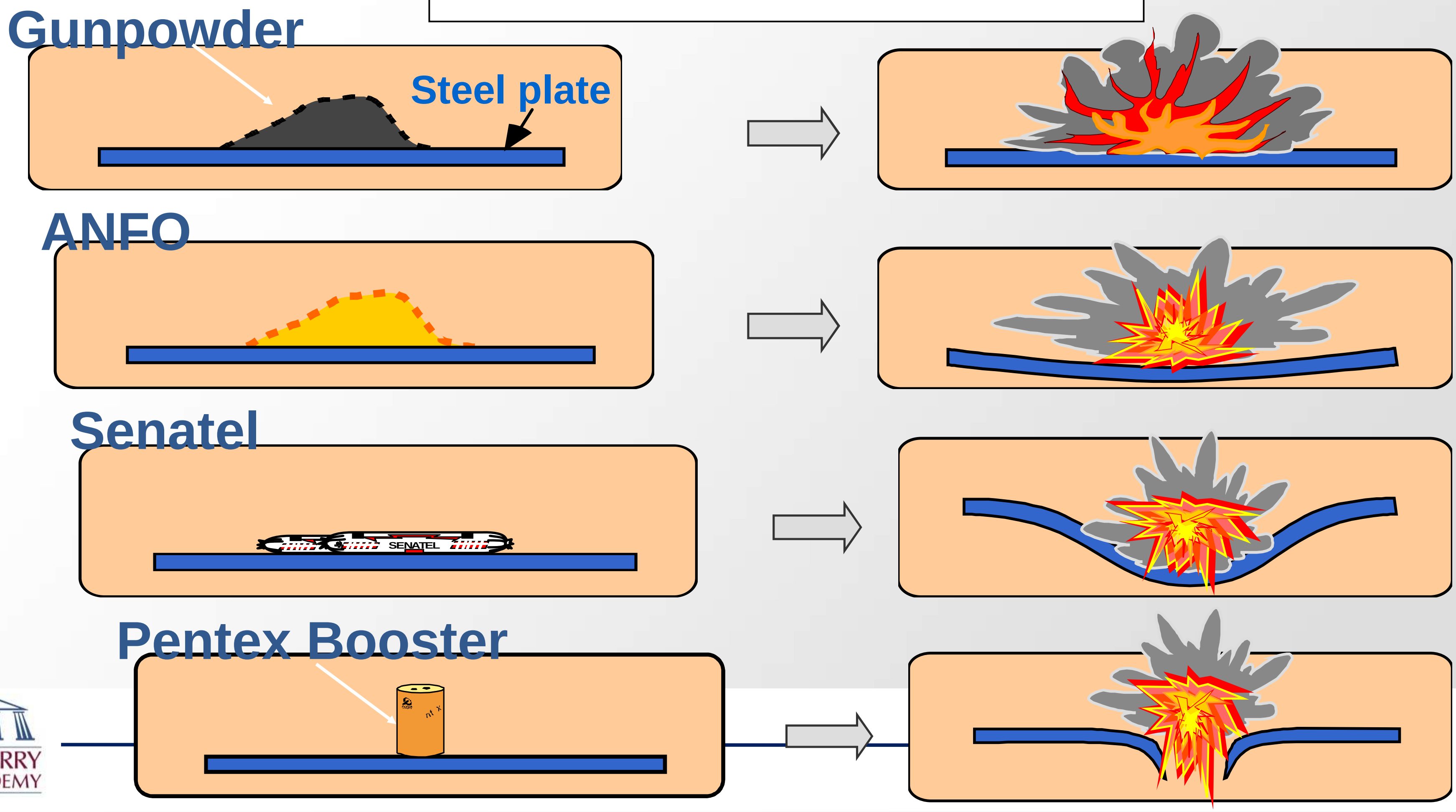
Detonation Pressures

Explosive	Pressure (kbars)
ANFO	34
Water Gel	76
Emulsion	100
Ammonia Gelatin Dynamite	135
Pentolite Cast Booster	240

BLAST EFFECTS



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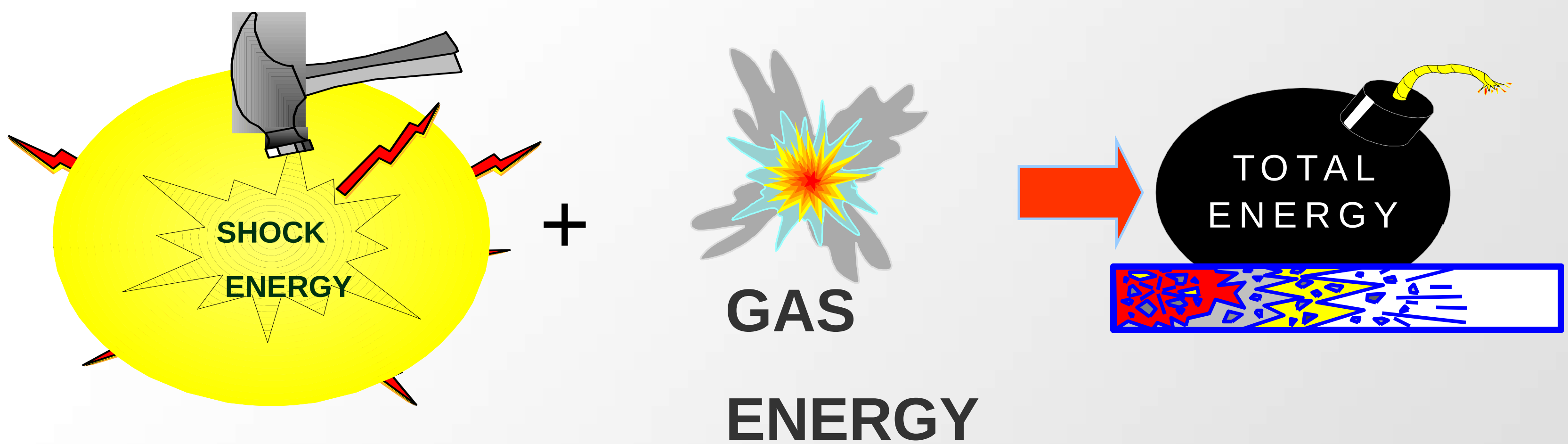
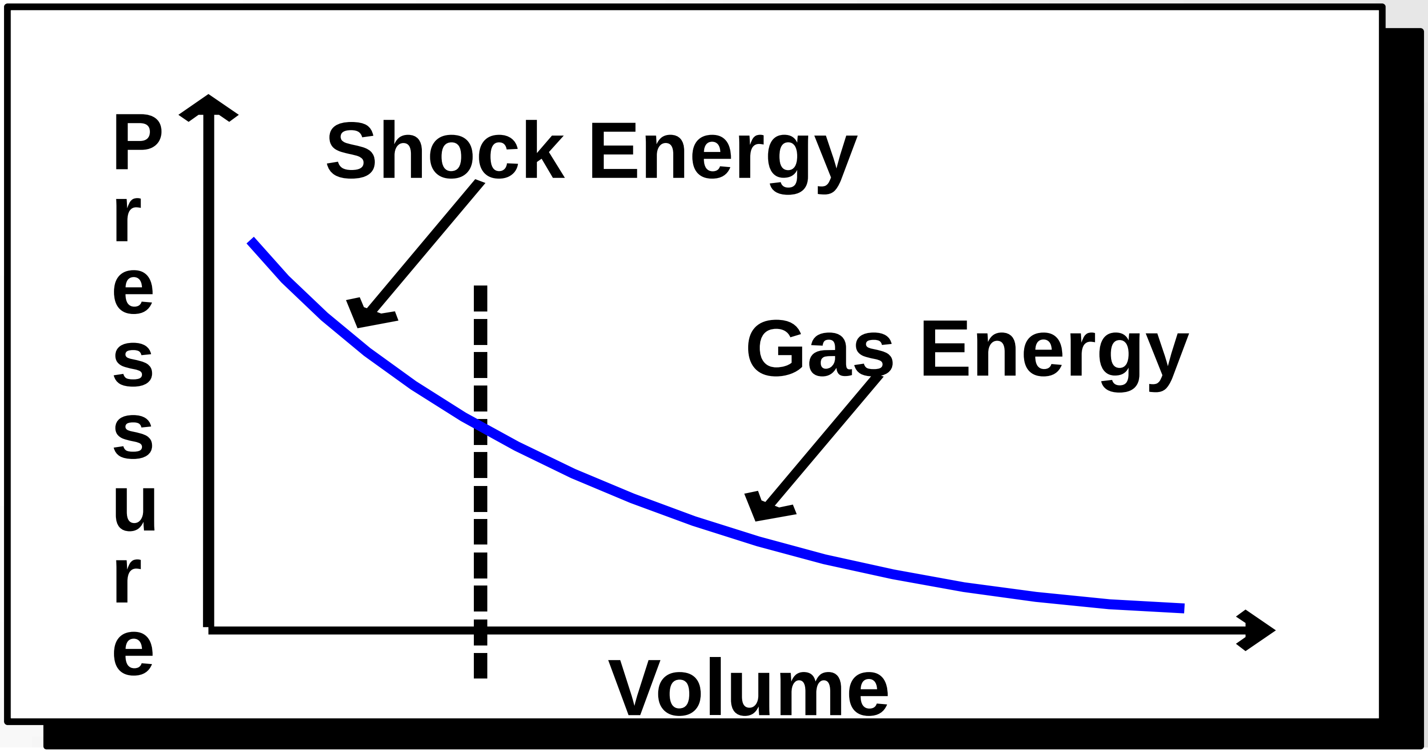
Booster on Steel Plate

EXPLOSIVES ENERGY



- **Shock Energy -- Affects Fragmentation**
- **Gas Energy -- Affects rockpile Looseness & Digability**

Energy Partitioning



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Shock Energy

Gas Energy

Absolute Weight Strength (AWS)

The Absolute Amount of Energy Available In Each <u>Gram</u> of Explosive

Absolute Bulk Strength (ABS)

The Absolute Amount of Energy Available In Each <u>Cubic Centimeter</u> 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

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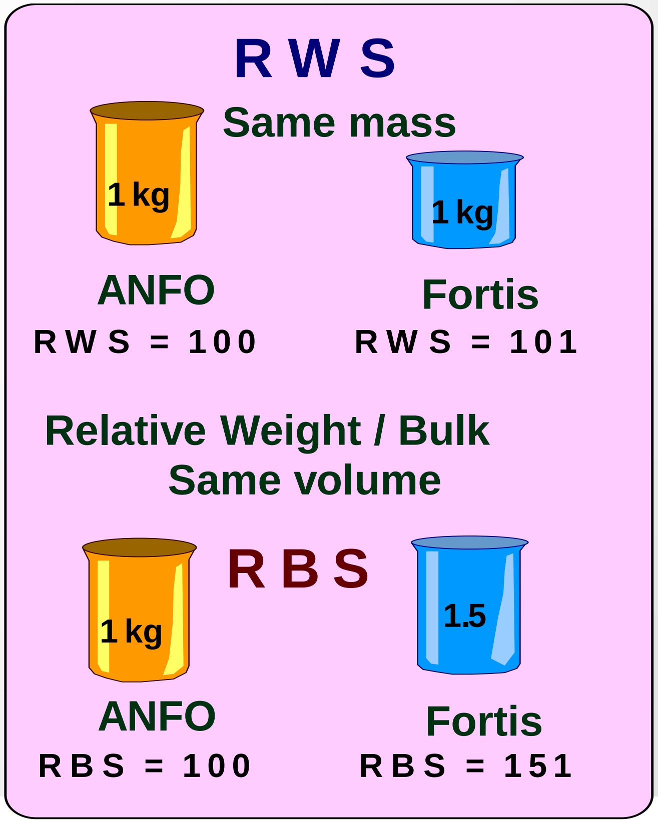
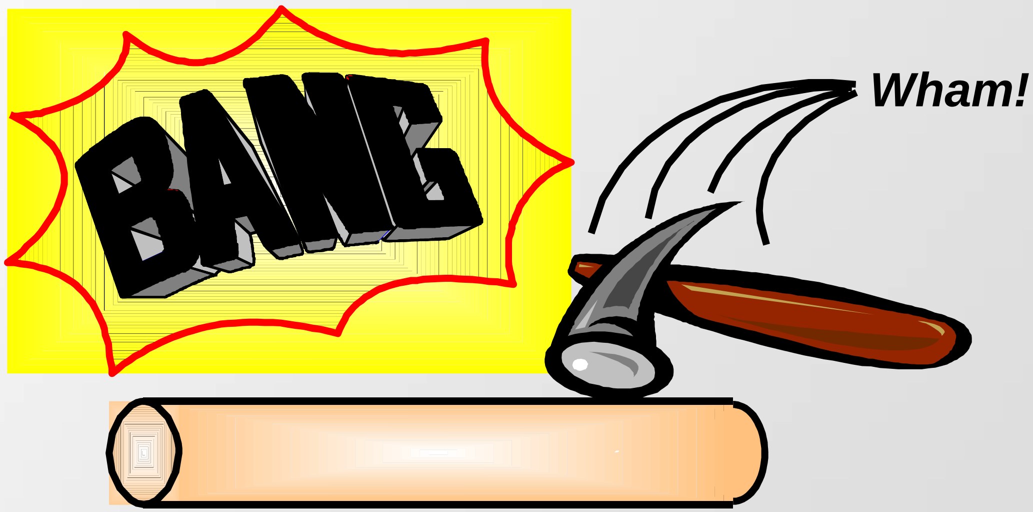
ENERGY RATINGS



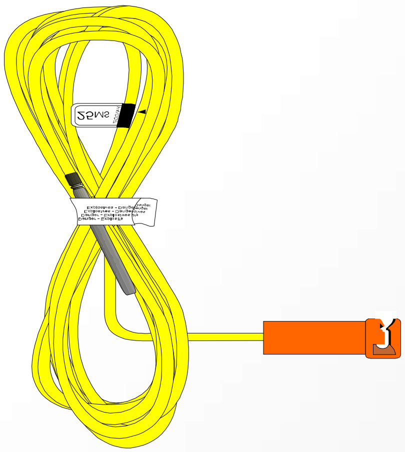
Sensitivity

Ease of Initiation by . . .

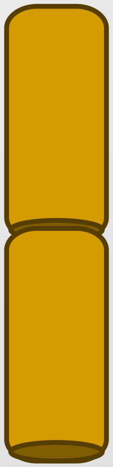
Shock
Impact
Friction
Heat



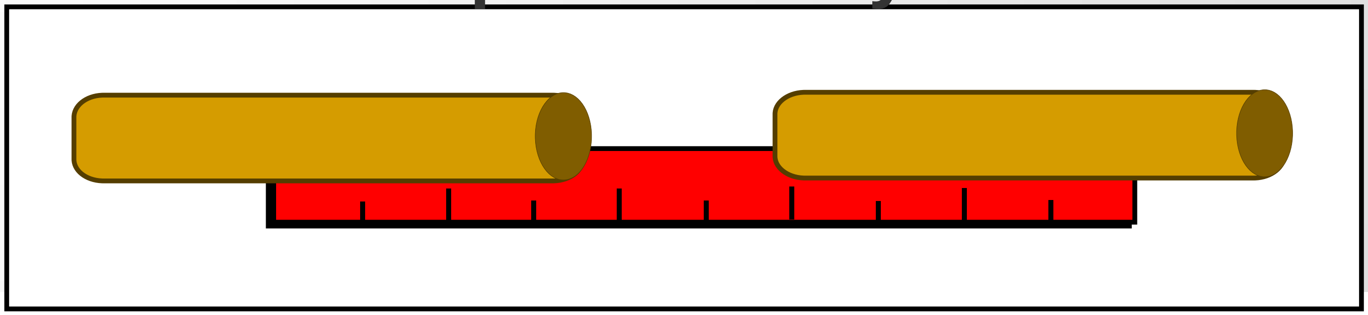
Sensitivity



Ability to Propagate



Gap Sensitivity



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UN Classifications for Explosives

1.1 Detonator Sensitive Explosive

1.4 Detonating Devices

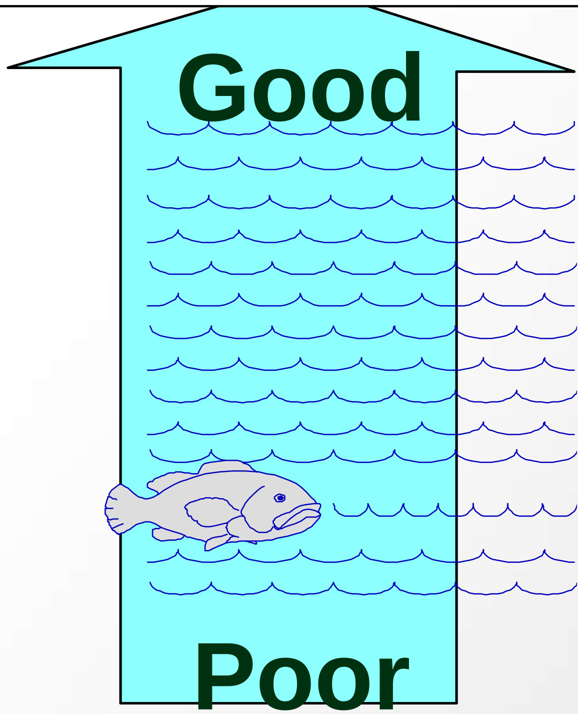
1.5 Booster Sensitive Explosive

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

WATER VAPOR

NITROGEN

OXYGEN

CARBON MONOXIDE

NITROUS OXIDES

HYDROGEN SULFIDE

OXYGEN BALANCE

O_2 Balanced

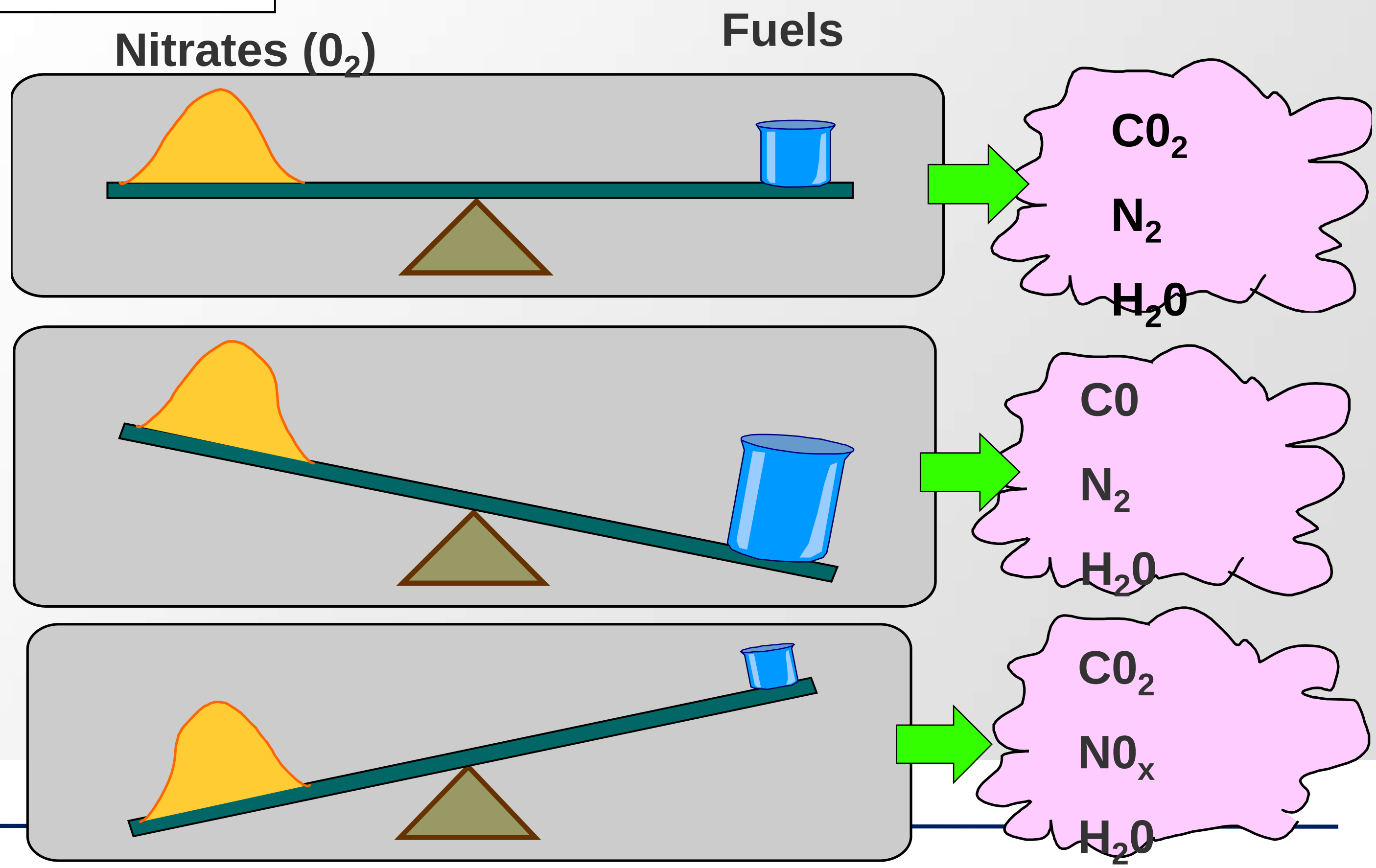
correct fuel

O_2 Negative

too much fuel

O_2 Positive

too much oxygen



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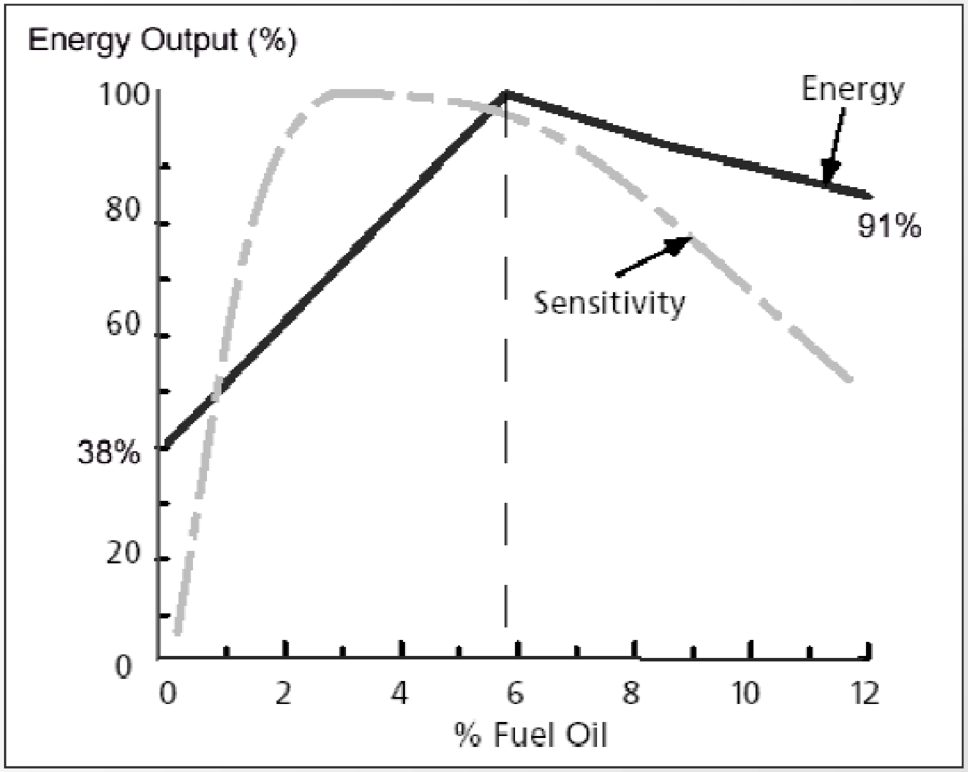
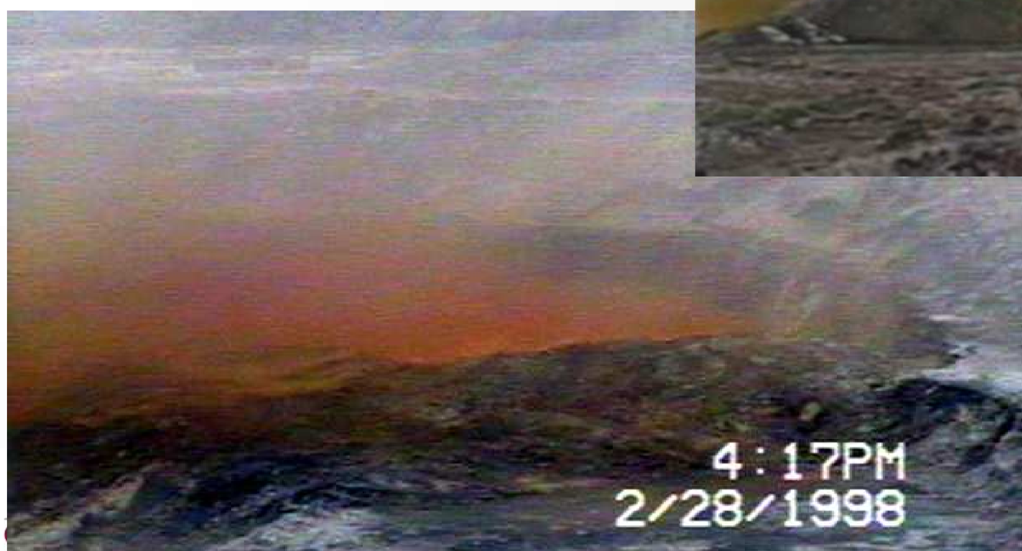
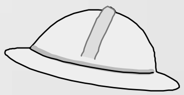

Energy Output (%)
100
80
60
38%
20
0
0
2
4
6
8
10
12
% Fuel Oil
Energy
91%
Sensitivity

NOx Post Blast Fume



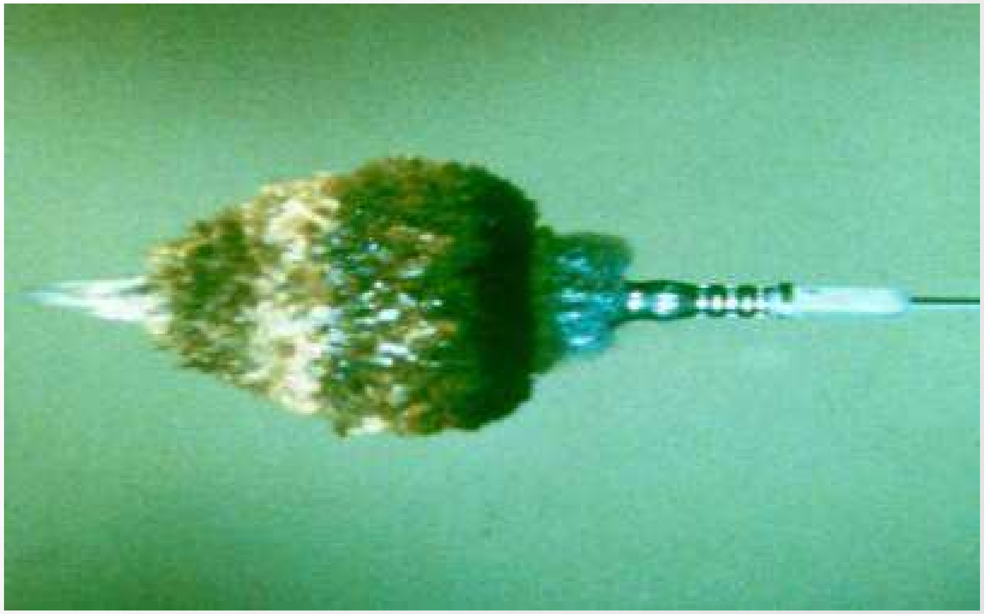
EXPLOSIVES SELECTION CRITERIA

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

Initiation Systems



Definition

An Initiation System …

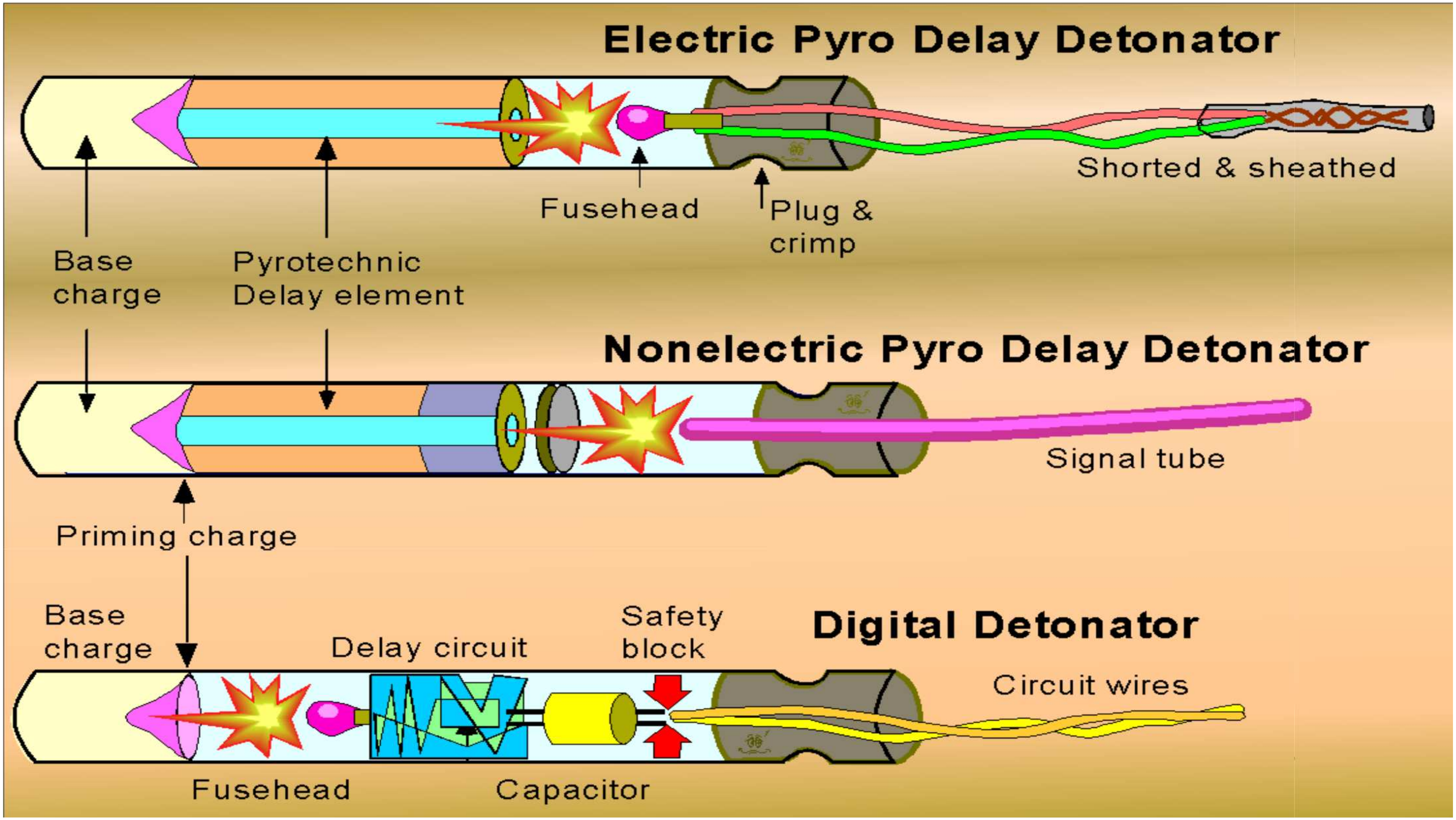
… is a means of

detonating high explosive charges **reliably**,

at the specified **time**

and

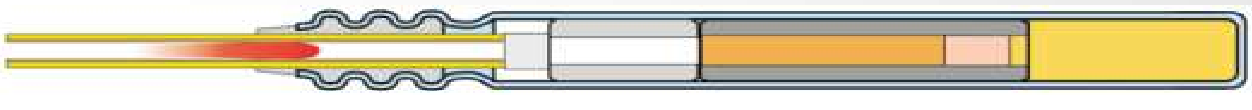
in the correct **sequence** ....



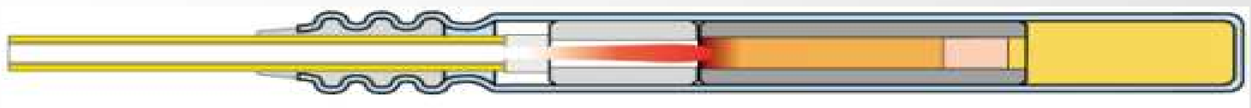
Electric Pyro Delay Detonator
Shorted & sheathed
Fusehead
Plug & crimp
Base charge
Pyrotechnic Delay element
Nonelectric Pyro Delay Detonator
Signal tube
Priming charge
Base charge
Delay circuit
Safety block
Digital Detonator
Circuit wires
Fusehead
Capacitor

Nonelectric Initiation

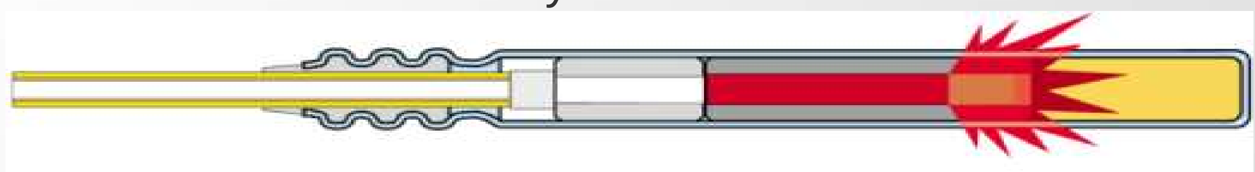
Mode of Operation



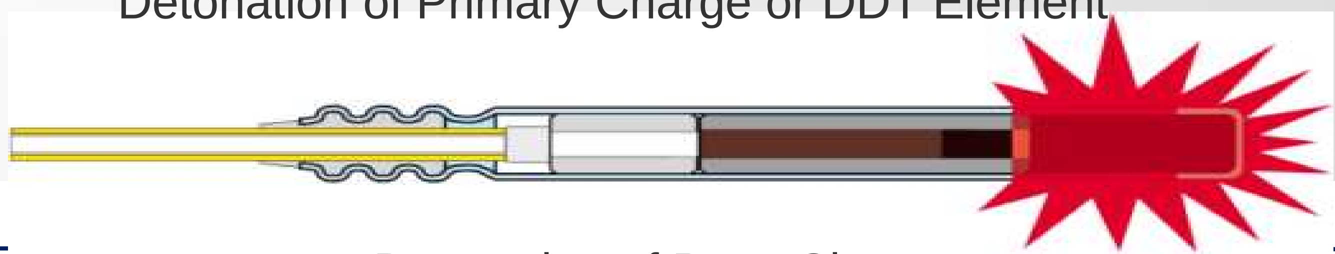
Shockwave travelling thru Shock Tube



Initiation of Pyrotechnic Element



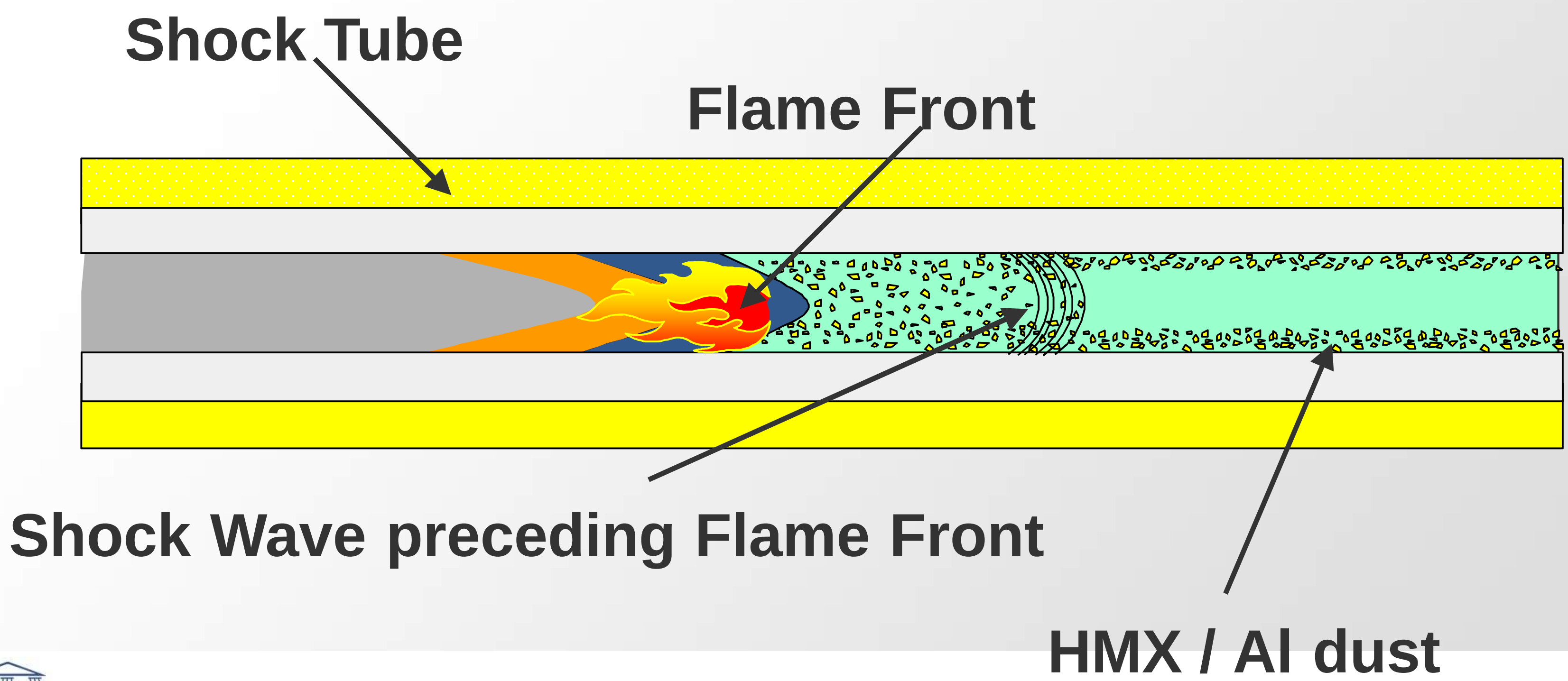
Detonation of Primary Charge or DDT Element



Detonation of Base Charge

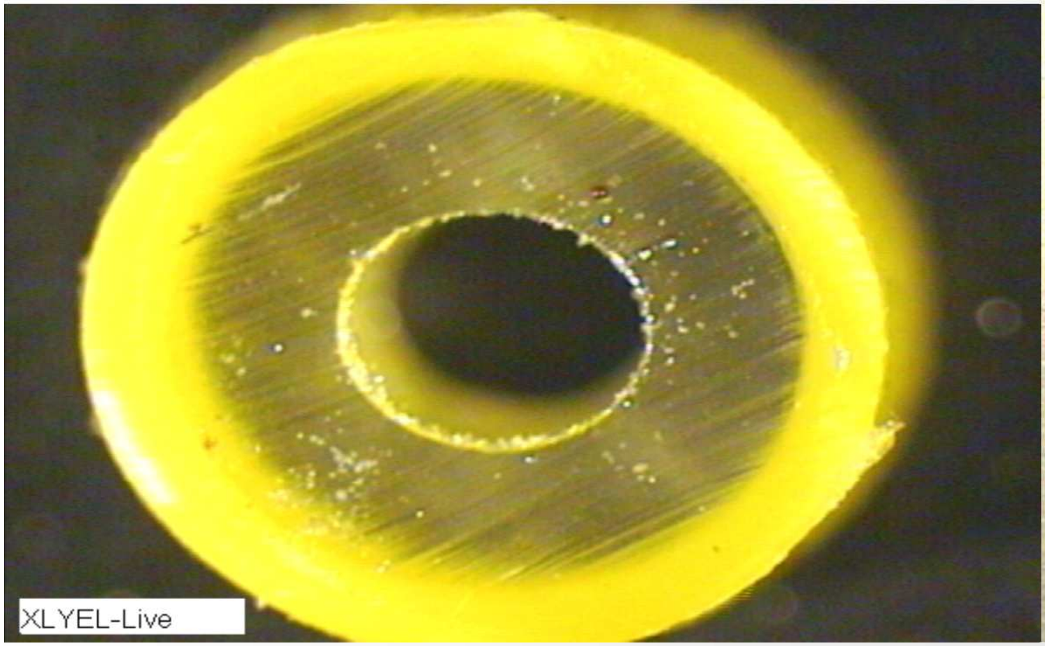
Nonelectric Initiation

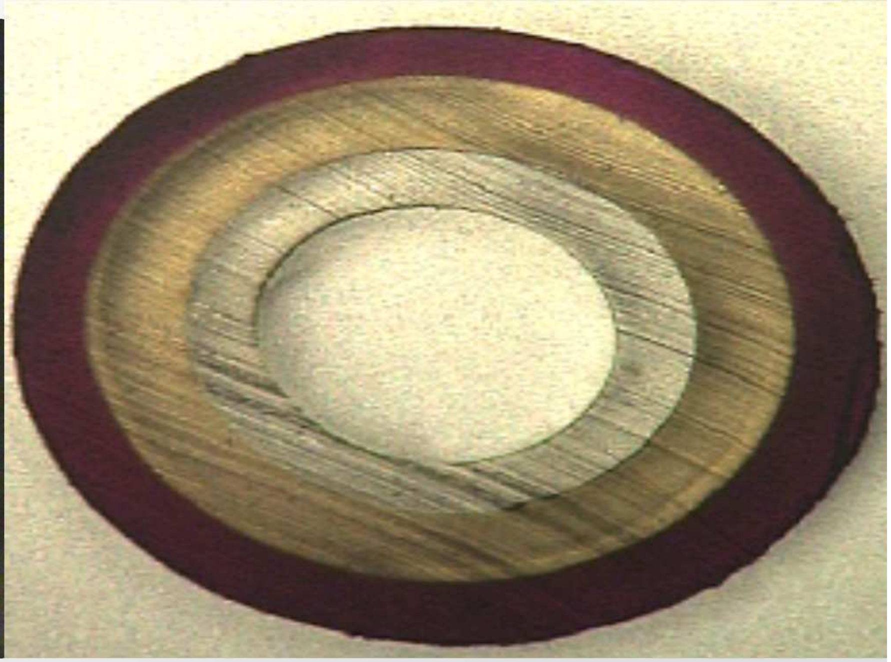
Shock Tube Functioning



Nonelectric Initiation

Shock Tube Construction





- Multiple Layers Tubes
- HMX / Al Dust Mixture
- Coreload Limits ≈ 15 mg/m

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Nonelectric Initiation

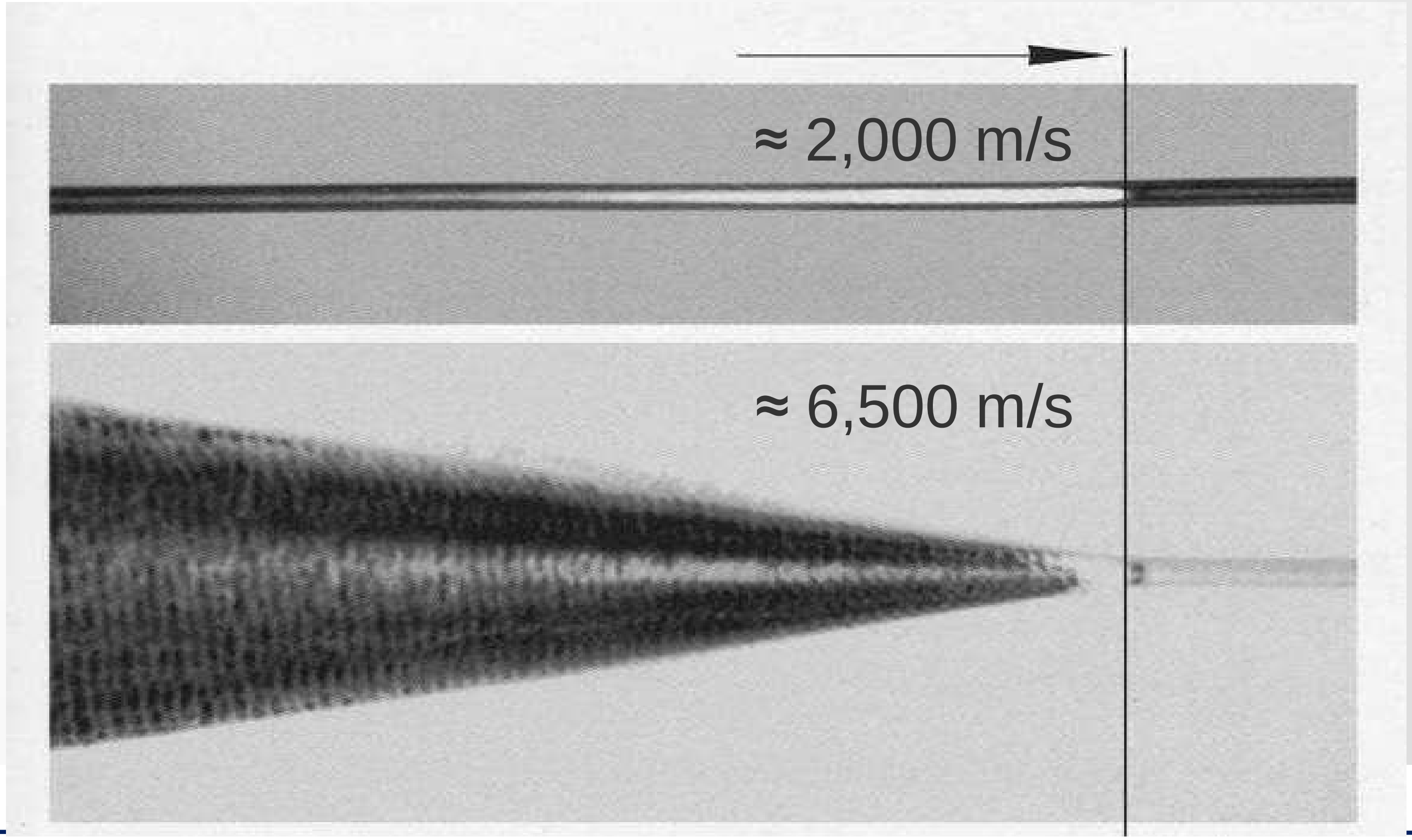
Shock Tube – Live & Fired

Shock Tube - Live

Shock Tube - Fired

Nonelectric Initiation

Shock Tube vs. Detonating Cord



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Nonelectric Initiation

3 Areas of Initiation System

Starter

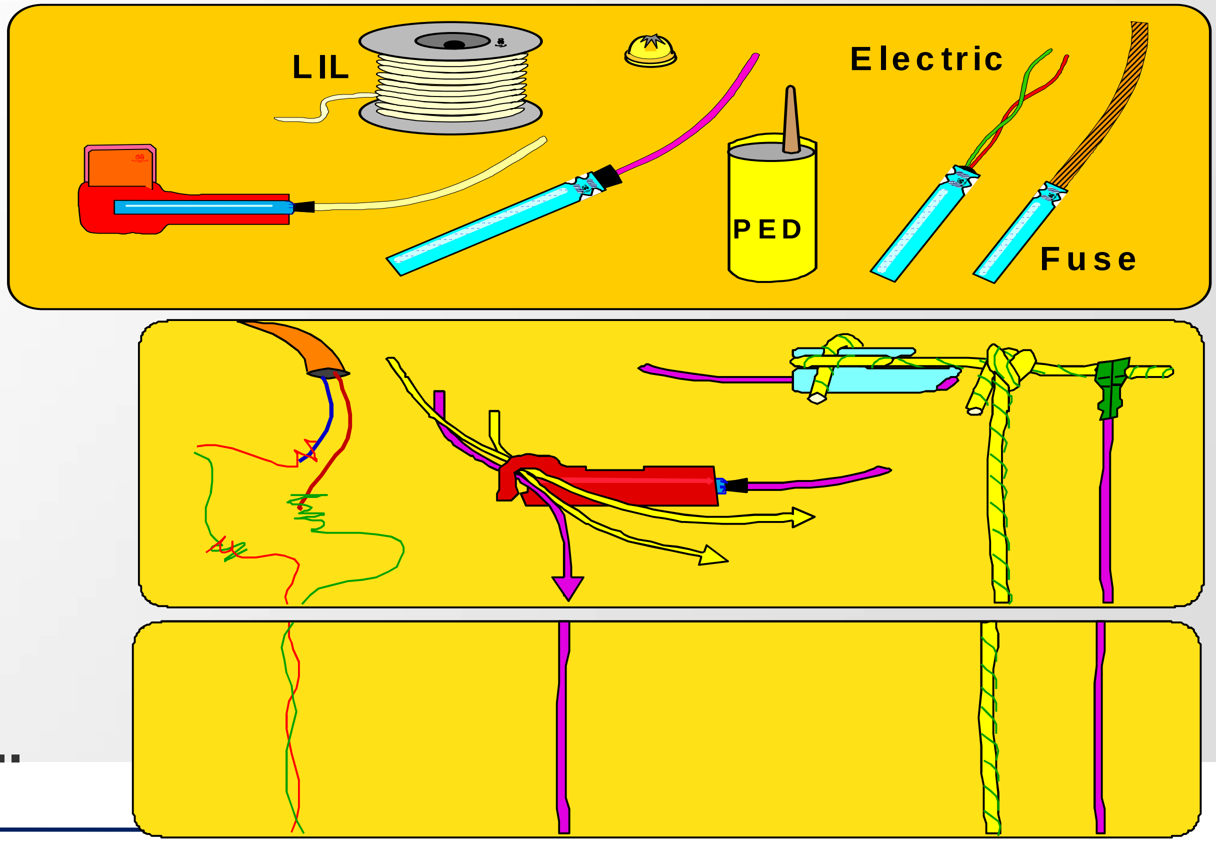
the key....

Surface

the distributor....

In hole

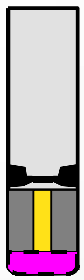
the transmission....



Nonelectric Initiation

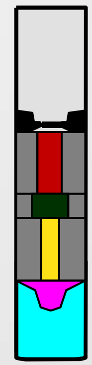
Surface Delay vs. Detonator Strength

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

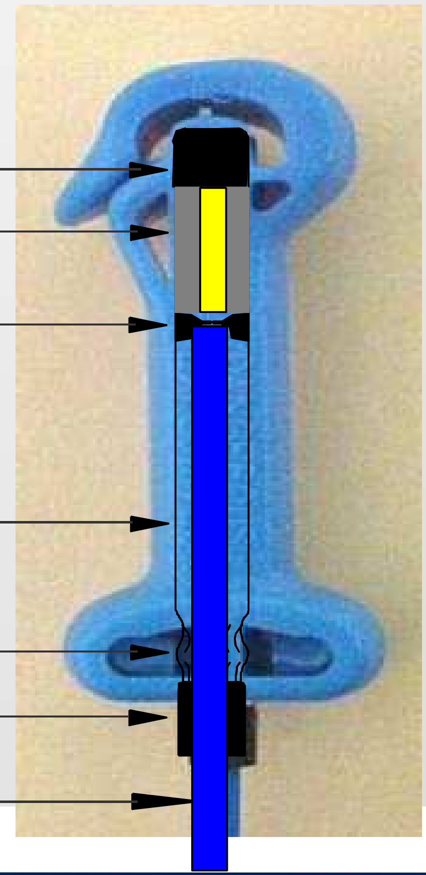
Isolation Cup

Free Space

Crimp

Rubber Bush

Shock Tube

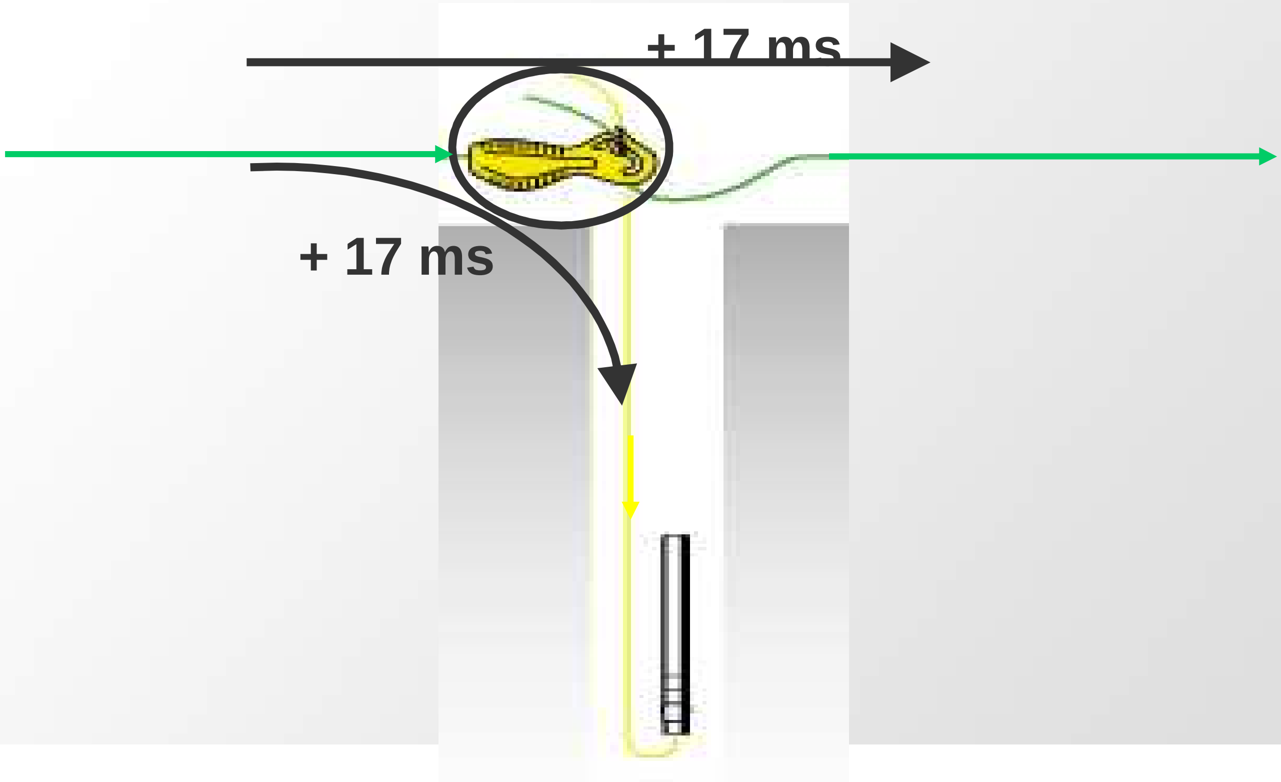


Nonelectric Initiation

Surface Delay - Construction

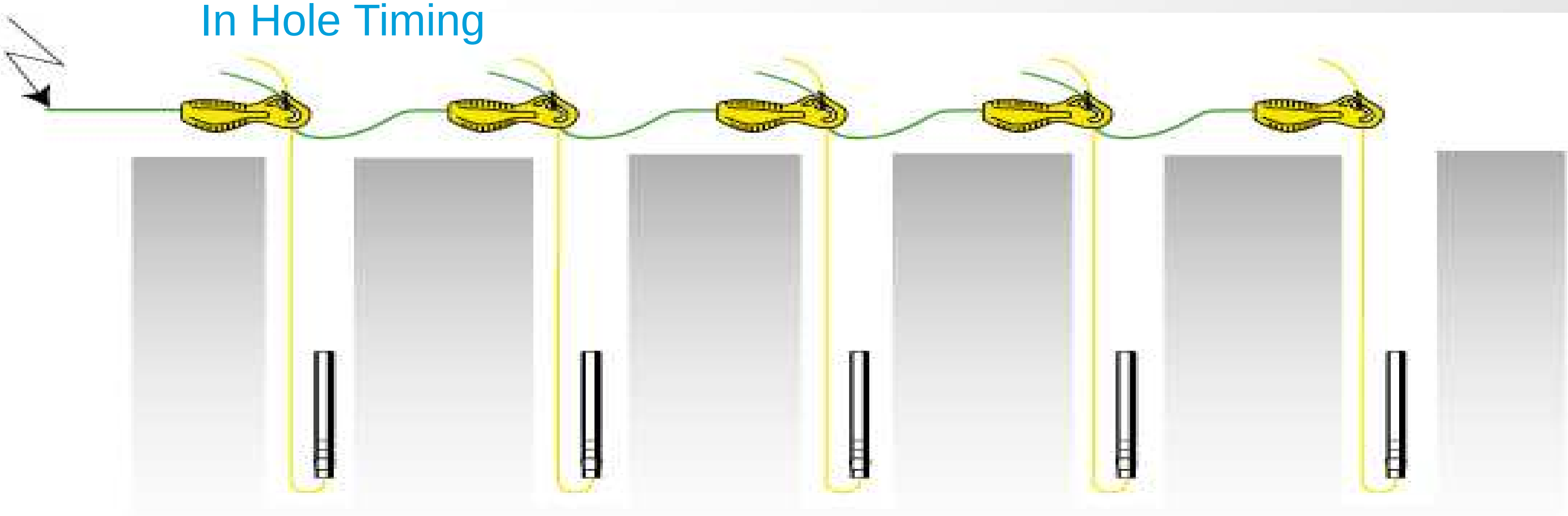
Nonelectric Initiation

Function Surface Delay



Nonelectric Initiation

In Hole Timing



500 ms	500 ms	500 ms	500 ms	500 ms
+ 17 ms	+ 17 ms	+ 17 ms	+ 17 ms	+ 17 ms
= 517 ms	+ 17 ms	+ 17 ms	+ 17 ms	+ 17 ms
	= 534 ms	+ 17 ms	+ 17 ms	+ 17 ms
		= 551 ms	+ 17 ms	+ 17 ms
			= 568 ms	+ 17 ms
				= 585 ms

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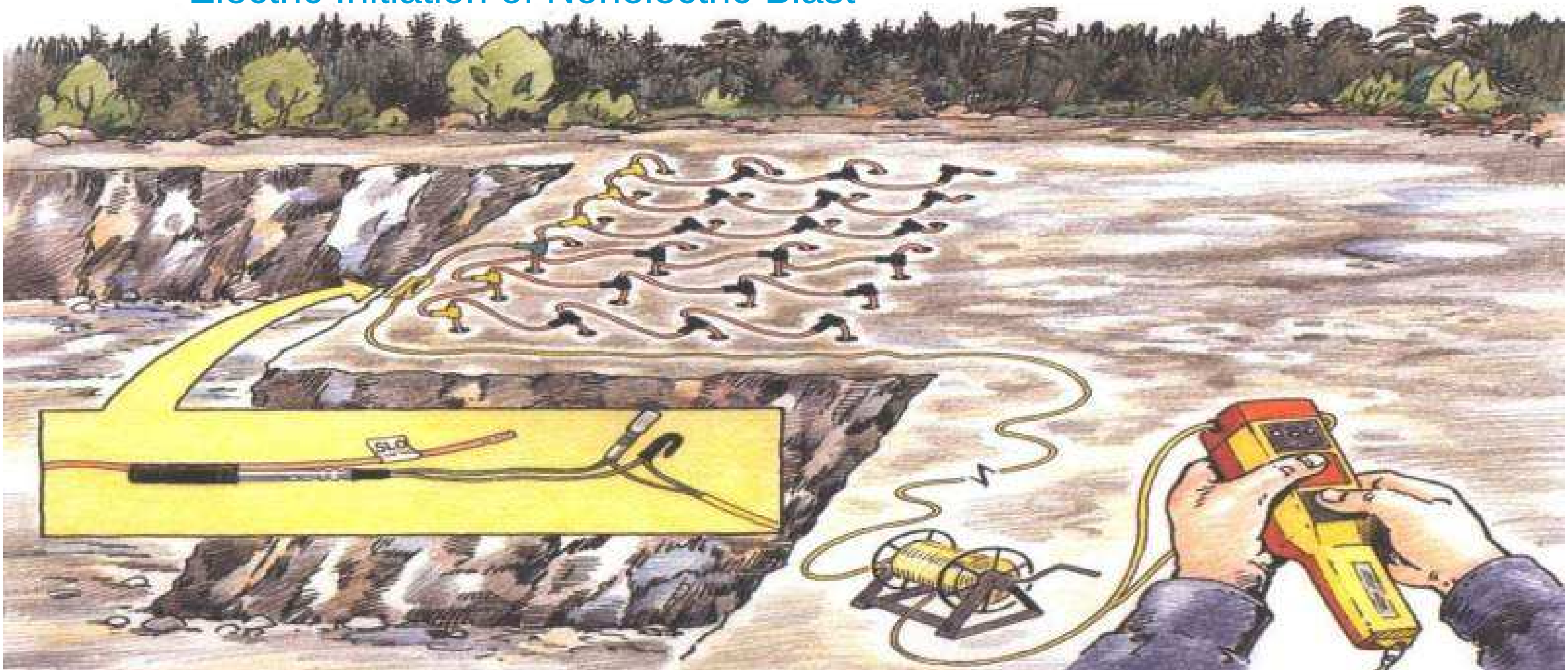
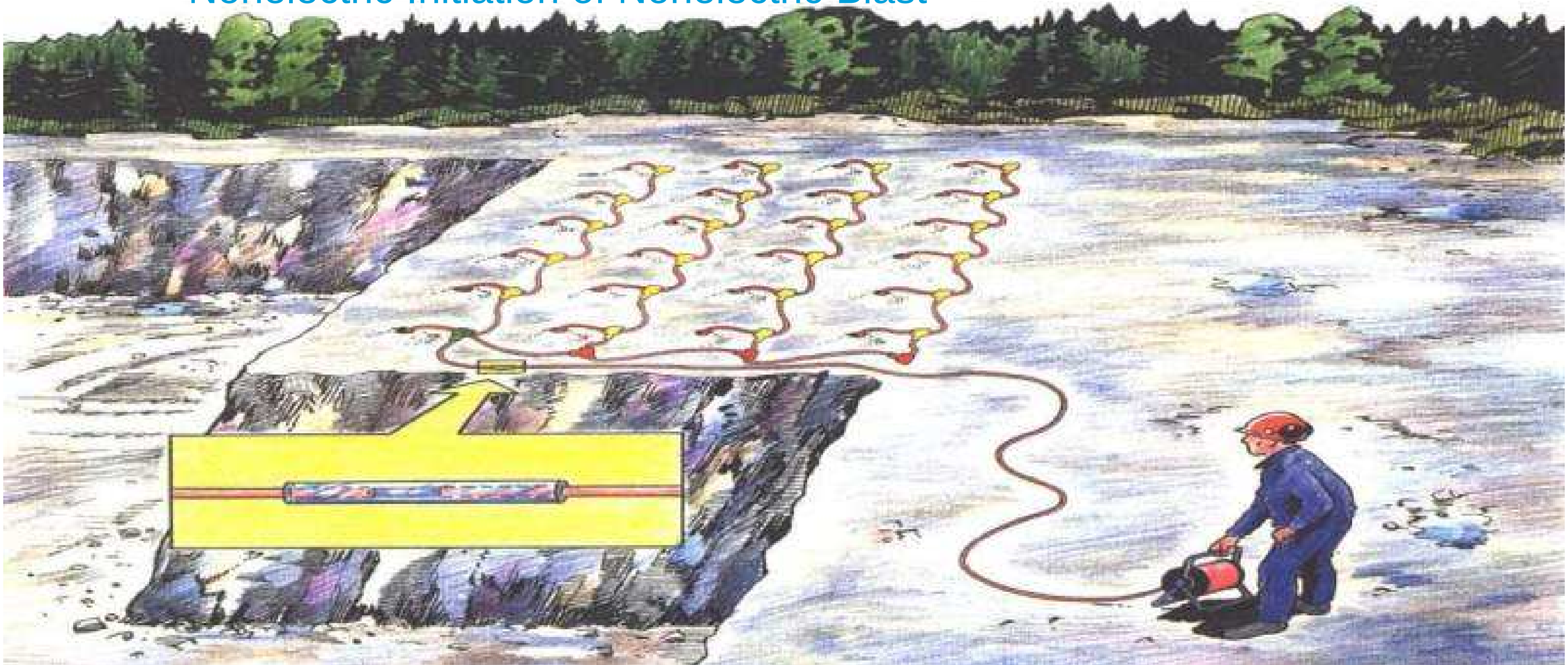
Nonelectric Initiation

Electric Initiation of Nonelectric Blast



Nonelectric Initiation

Nonelectric Initiation of Nonelectric Blast



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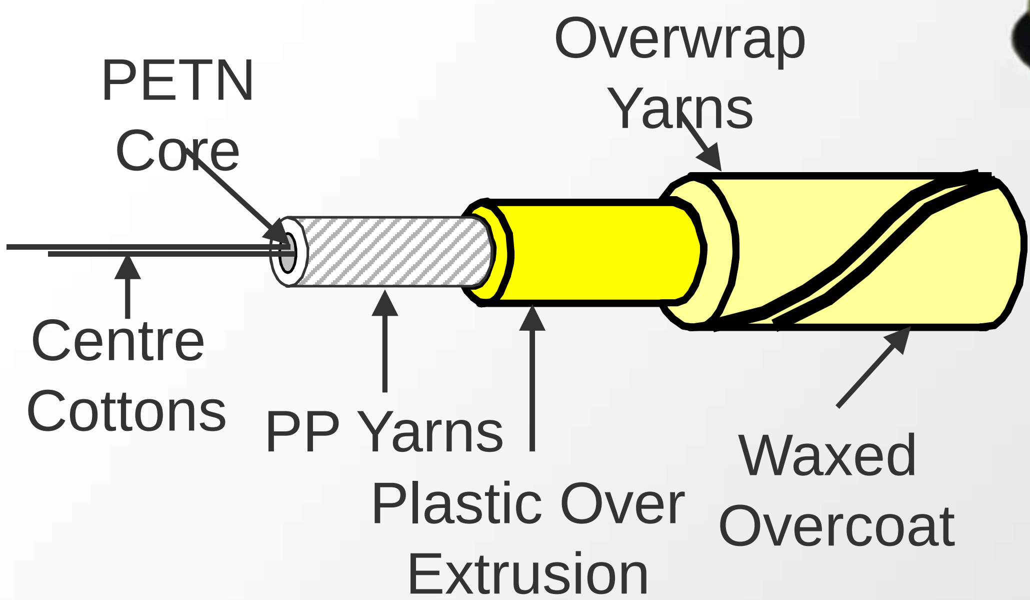
Detonating Cord

Cord Construction



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Detonating Cord

Cord Types

'Cordtex' 3.6 'W'
Uniflex

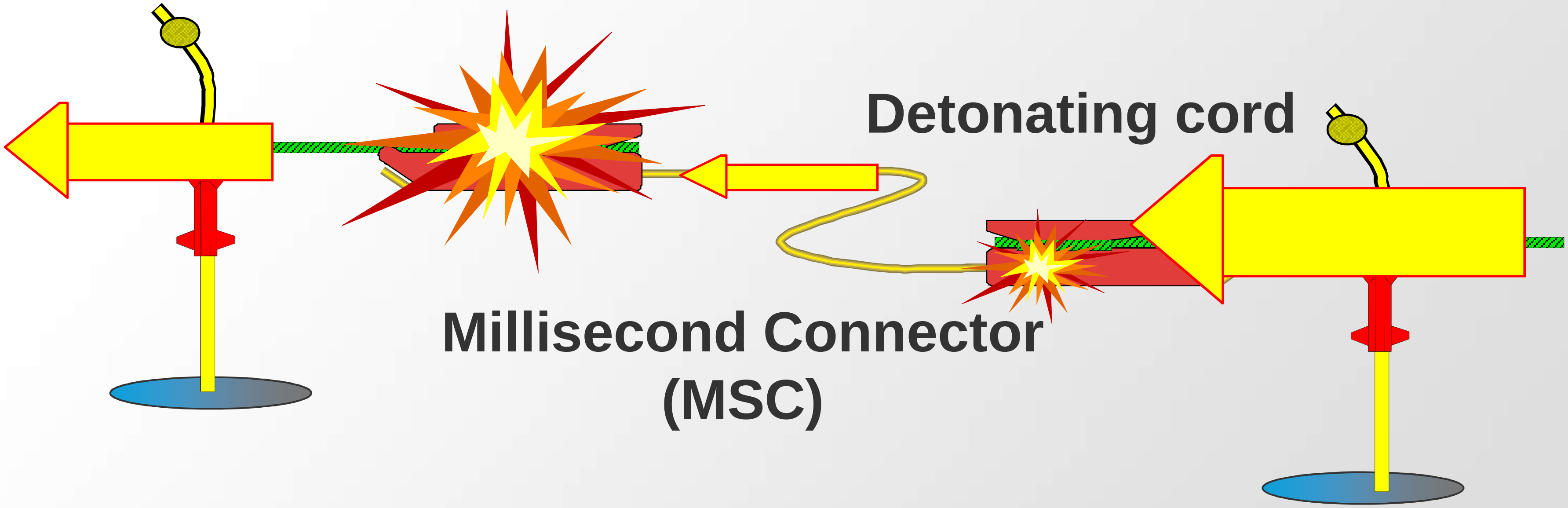
'Cordtex' 5 'W'
'Cordtex' 5 'P'

'Cordtex' 10 P
Redcord
'Profiler'

3.6 g/m
5 g/m
5 g/m
10 g/m
70 g/m

Detonating Cord

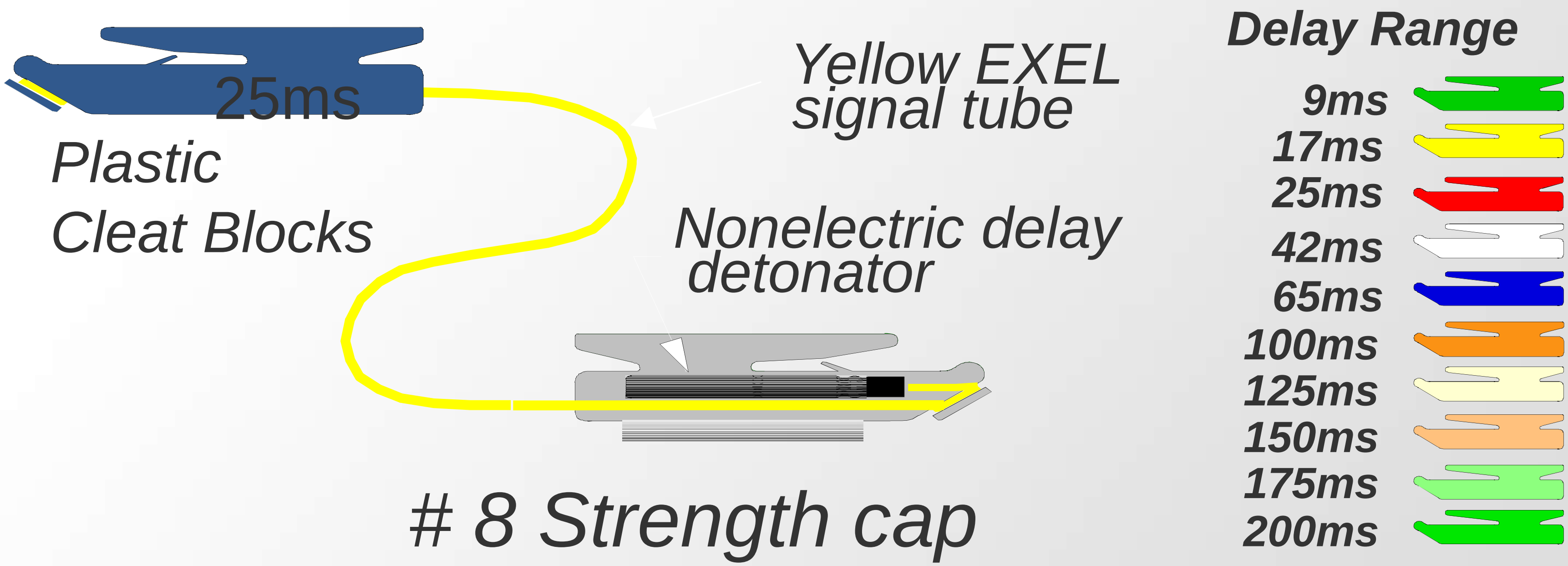
MS Connector



to Fire detonating cord ONLY

Detonating Cord

MS Connector



to Fire detonating cord ONLY

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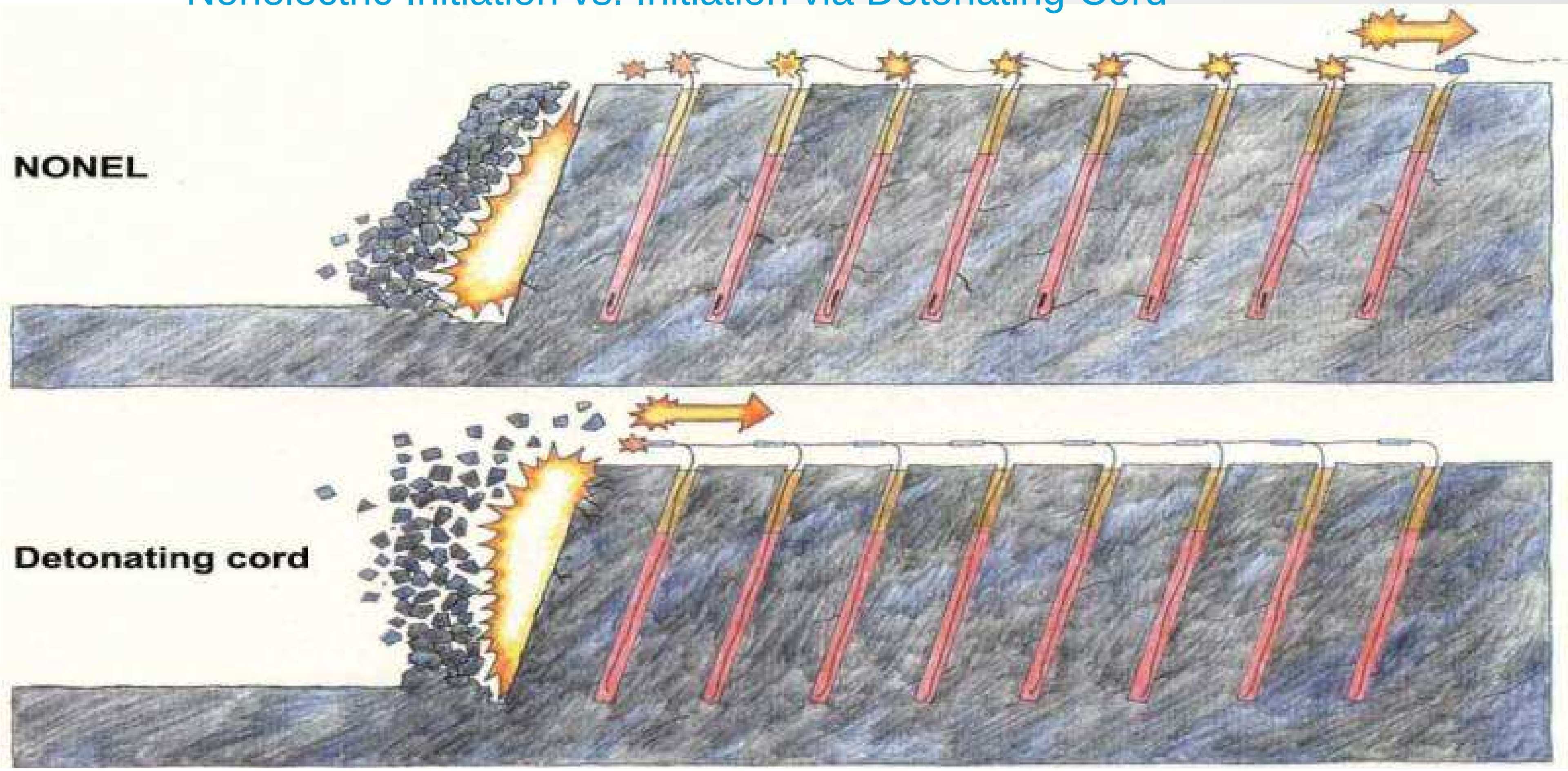
Nonelectric Initiation

Nonelectric Initiation vs. Initiation via Detonating Cord



Nonelectric Initiation

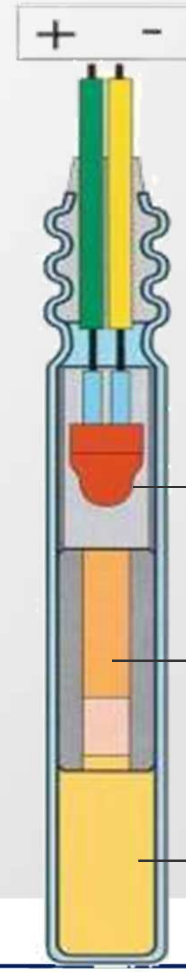
Pro´s and Con´s

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

Detonator Construction



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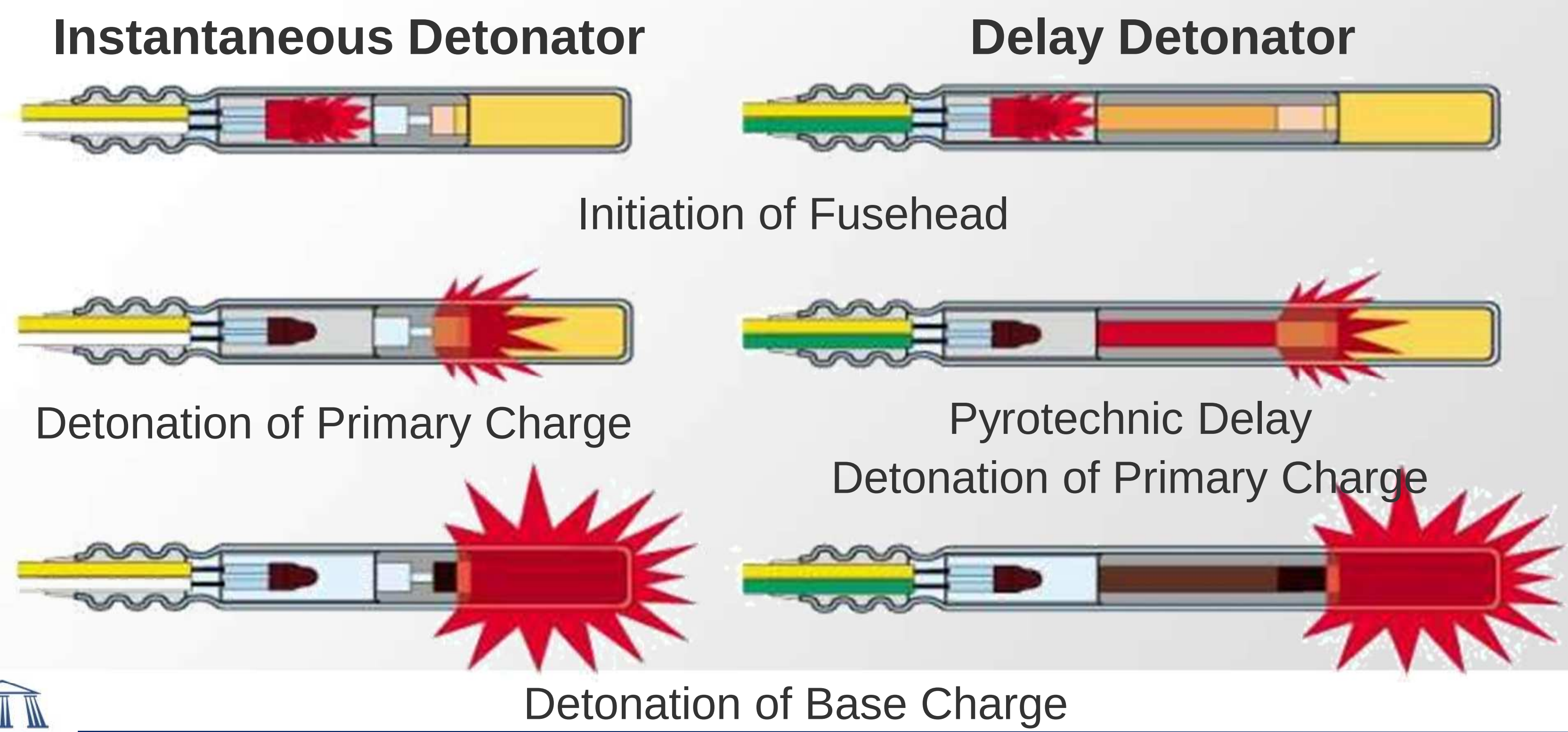
Electric Initiation

Mode of Operation

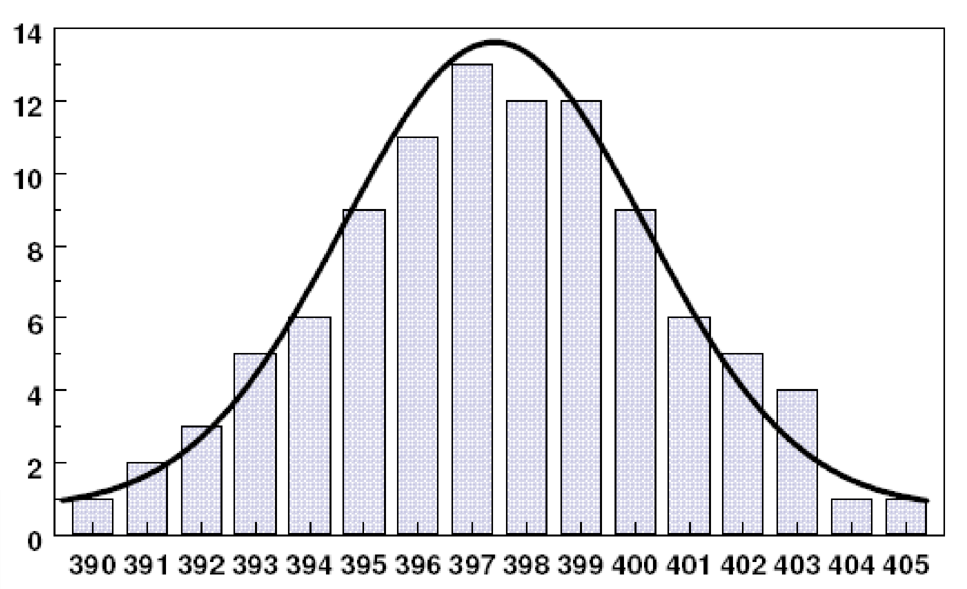


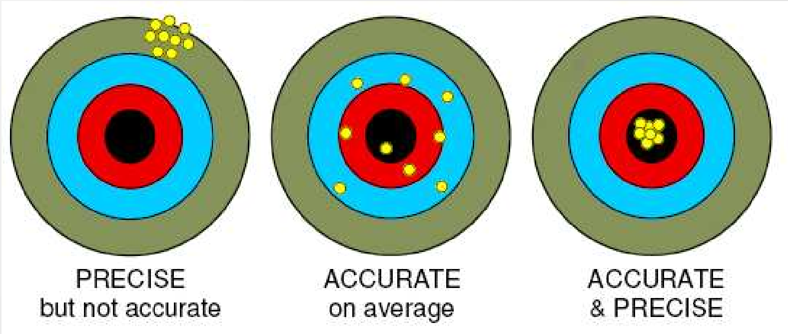
Electronic Initiation

Detonator Construction

Electronic Initiation

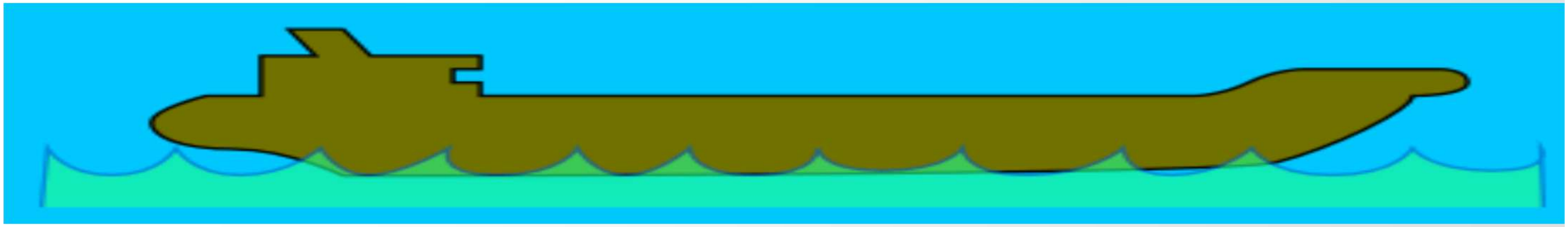
Precision & Value





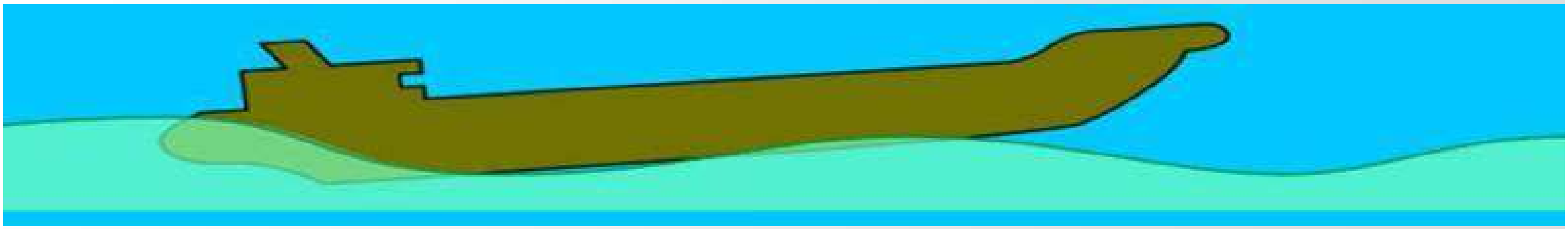
Electronic Initiation

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**

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