Explosive Characteristics

Scott G. Giltner

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Explosive Properties

- Physical properties
  - ✓ Give an indication of the application in which they can be used
- Detonation properties
  - ✓ These properties are used to describe the performance of explosives
- Safety properties
  - ✓ These describe the handling requirements for different products

All properties are equally important when selecting explosives.

Physical Properties

- Density
- Water resistance
- Chemical stability
- Fume characteristics
- Sleep time
- Viscosity
- Form / Configuration

Density

- Important property for explosive selection.
- Density below 1.0 g/cm^3 means explosive will float in water.
- Increasing density leads to increasing VOD up towards the explosive composition's critical density.
- Higher density in non-ideal explosives risks dead pressing.
- Important to determination of loading density (kg/m or lb/ft).
- Normally the density of a single explosive composition remains relatively constant over a borehole's length. Bulk explosive compositions that can be chemically sensitized/density modified during loading can provide varying densities along a blasthole's length!

Water Resistance

Ability of explosive ability to withstand exposure to water without losing sensitivity or efficiency

- **Wide variation:**
  - ✓ **ANFO has none**
  - ✓ **Emulsion is excellent**
  - ✓ **Emulsion / ANFO blends vary with percentage of composition.**
- **Dependent on water conditions**
  - ✓ **Static or dynamic water**
  - ✓ **pH of ground water can also affect water resistance**
- **Orange-Brown Nitrous Oxide fumes post blast can be indication of water damage to explosive. (indicator of lost efficiency)**
- **Water resistance of explosives can be improved by use of hole liners, but usually at the risk of reduced charge per foot of blasthole.**

Chemical Stability

Defined as the ability to remain chemically unchanged when stored correctly. It is a key parameter determining the shelf life of many products

- **Factors affecting shelf life include:**
  - ✓ **Formulation/Raw material quality**
  - ✓ **Packaging Integrity**
  - ✓ **Temperature and humidity changes in storage environment**
  - ✓ **Contamination**
- **Characteristic signs of deterioration include:**
  - ✓ **Crystallization (ANFO, Emulsion and Dynamites)**
  - ✓ **Increased viscosity and/or density (Emulsion and Emulsion ANFO blends)**
  - ✓ **Color change (e.g. bulk emulsions go cloudy as crystallization increases)**
  - ✓ **Poor field performance**

Fume Characteristics

- **Oxygen balanced explosives yield non toxic gases (CO_2, N_2 and H_2O) when they detonate efficiently. These normally are termed as "IME Fume Class 1"**
- **Minor quantities of toxic gases are also produced.**
  - ✓ **Oxides of nitrogen (NOx) result from an excess of oxygen in the formulation (oxygen positive)**
  - ✓ **Carbon monoxide (CO) results from a deficiency of oxygen in the explosive (oxygen negative)**
- **Application conditions can alter the fume characteristics of an explosive. Increasing the production of toxic gases.**
  - ✓ **Water intrusion into the explosive composition, static and dynamic pressures, changes in diameter etc.**

Sleep Time

- **Wet or dry ground**
  - ✓ **pH of ground water**
- **Product type selected**
- **Ground type**
  - ✓ **Reactive**
  - ✓ **Temperature**
    - Hot
    - Cold

Viscosity

- **A characteristic of bulk or packaged emulsions and bulk or packaged water gels that are not cross linked.**
- **The higher the viscosity of the explosive emulsion or water gel.**
  - ✓ **Better the water resistance**
  - ✓ **Lower its flow properties**
    - Harder to pump
      - Need water injection to facilitate pumping or must be augered.
    - More resistant to moving out of the cracks or fissures in the boreholes and into the rock mass during or after loading.
- **The viscosity of some emulsion explosives are increased as they are pumped / loaded into the borehole.**
- **As solids (ANFO) are blended with emulsions and water gels their viscosity increases with as the percentage of solids increases.**

Form / Configuration

- **Packaged**
  - ✓ **Available Package Diameters**
  - ✓ **Available Package Weights**
  - ✓ **Type of package**
    - Does explosive rely on package to provide water resistance
    - Can the explosive be loaded without its package. (slit or cut into pieces)
      - Not recommend with any Dynamite.
- **Bulk**
  - ✓ **Dry Blend/Free Flowing**
  - ✓ **Wet Blend/Augerable**
    - Delivery rate
  - ✓ **Pumpable Blend**
    - Delivery rate

Detonation Properties

- Velocity of detonation (VoD)
- Detonation pressure
- Energy / strength
- Critical density
- Critical diameter
- Confinement

Velocity of Detonation (VoD)

Speed that the detonation wave travels through the explosive, usually expressed in meters per second (m/s) or feet per second (ft/s)

- ✓ **Influenced by:**
  - Rock Type
  - Charge diameter
  - Explosive density
  - Explosive formulation
  - Particle size
  - Degree of confinement
  - Primer (size and type)
- ✓ **VoD will influence how the energy is released from the explosive (i.e. the time period over which the energy will be released and the partitioning of the energy into shock and heave).**

Velocity of Detonation (VoD)

VoD is a guide to determining the efficiency of the explosive.

- ✓ **Comparison of VoD results should be done within the context of the particular blasting situation (i.e. same mine, same rock type). For Example, ANFO VoDs vary from 2500 to 4500 m/s (8200-14700 ft/s) depending on hole diameter in the same rock.**
- ✓ **VoD data should be seen as a statistical variable (i.e. get multiple data wherever possible) to allow for:**
  - Rock type variation
  - Charging variation
  - Data capture system

Detonation Pressure P_d

- Pressure in the detonation reaction zone as it progresses along a charge, expressed in GPa or Kbar. This is what generates the shock pulse in rock.
- P_d estimation for commercial explosives:

$$P_d = 2.5 \times VoD^2 \times \rho$$

eg. ANFO at ρ = 0.85 g/cc and VoD = 4,000 m/s

$$P_d = 2.5 \times (4000)^2 \times 0.85$$

$$= 3.4 \text{ GPa or } 34 \text{ Kbar}$$

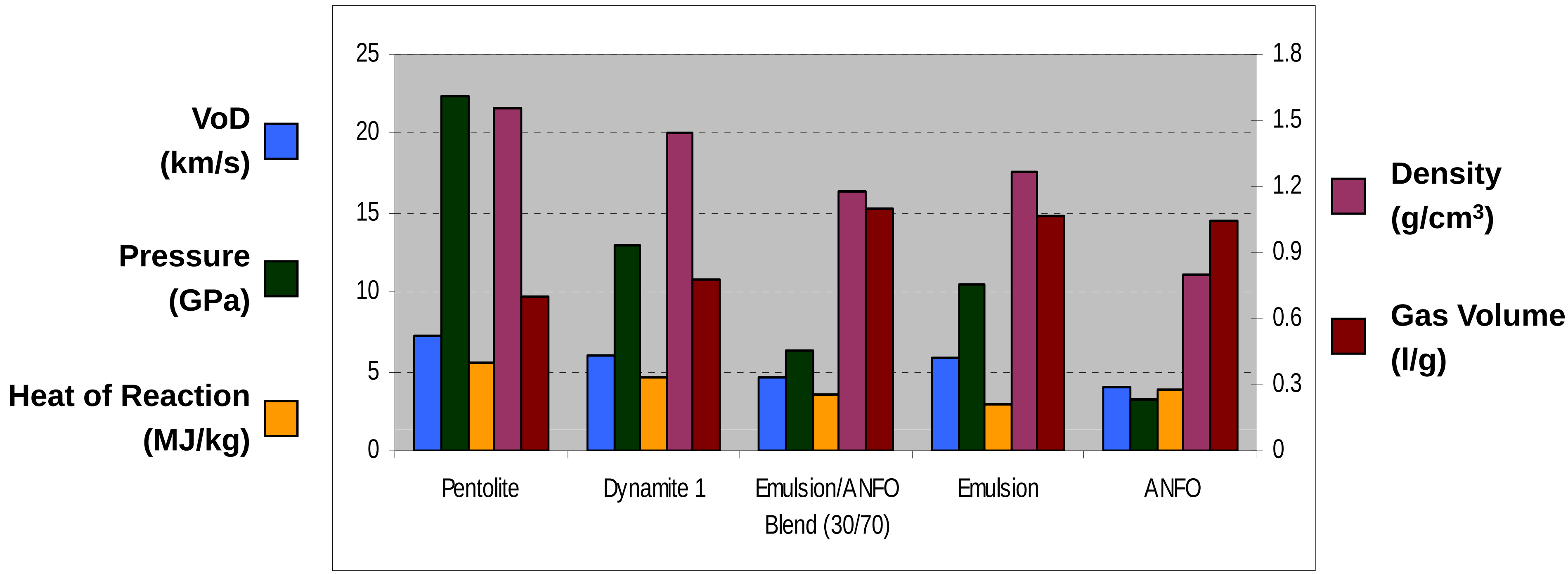
PSI = 14,504 (psi) x 34Kbars = 493,136

Detonation Pressure P_d

(calculated by $P_d = 2.5 \times \rho \times VoD^2$)

		VoD (m/s)	Density (g/cm^3)	P_d (Kbar)
Secondary Explosives	PETN	8,300	1.56	269
	RDX/TNT 60/40	7,900	1.72	268
	TNT	6,950	1.57	190
Packaged Explosives	Semi Gelatin Dynamite	4,300	1.30	60
	Extra Gelatin Dynamite	6,000	1.45	130
	Emulsion 1.5B	5,000	1.26	79
	Emulsion/ANFO 1.5B	5,600	1.29	108
Bulk Blasting Agents	Emulsion	5,800	1.25	105
	Emulsion/ANFO Blend (70/30)	5,600	1.29	101
	Emulsion/ANFO Blend (30/70)	4,700	1.31	72
	ANFO	4,000	0.85	34

Comparison of Explosives

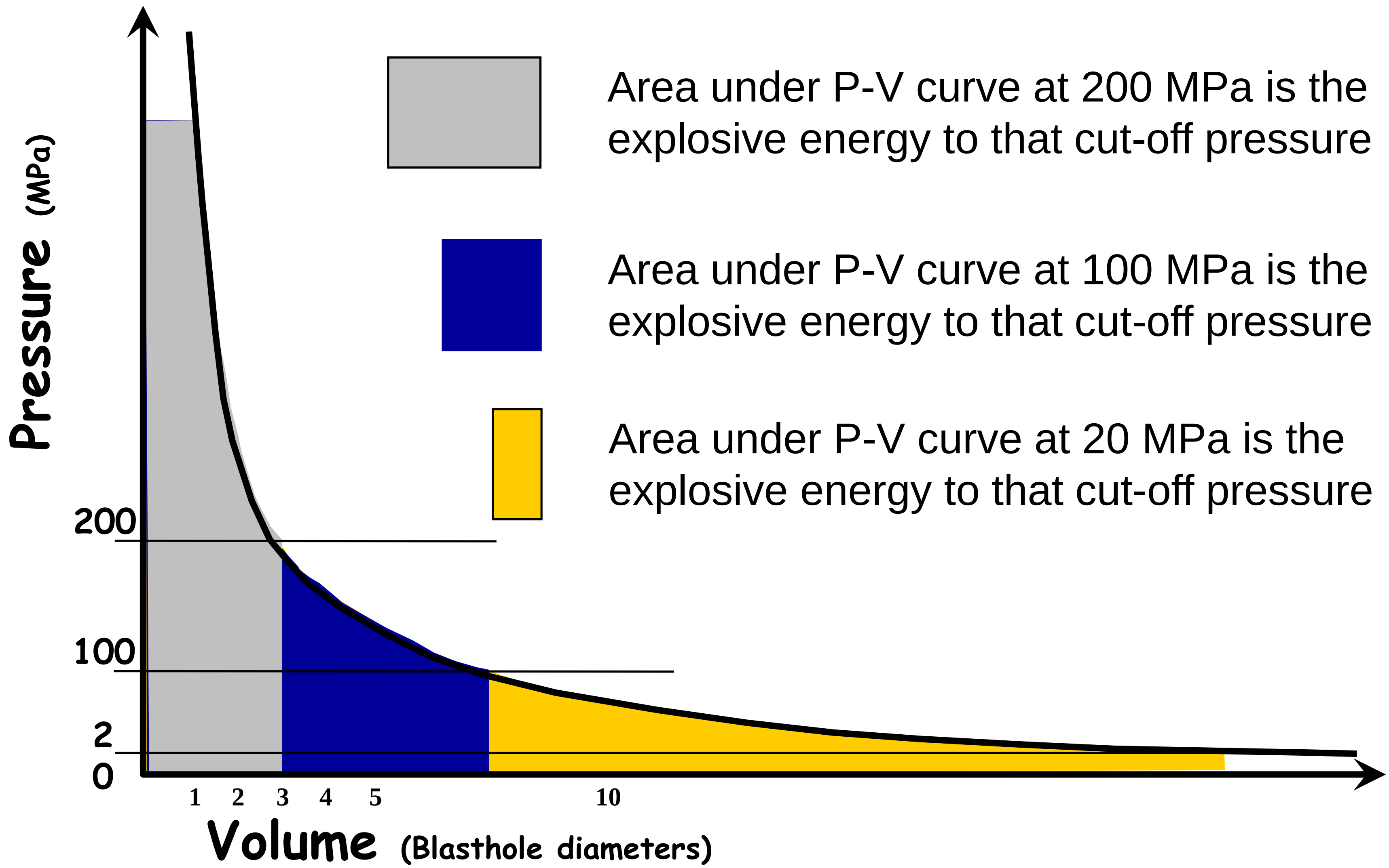


Available Explosives Energy

The energy that an explosive is able to deliver to do useful work:

- ✓ **Energy delivered to the rock mass before the gasses vent to the atmosphere (Calculated using thermodynamic codes)**
- ✓ **Actual amount of energy delivered in any blast is unknown - too many variables**
- ✓ **One critical factor is the cut off pressure assumed in any energy calculation**
  - Changing the cut off pressure will change the energy attributed to an explosive.
  - Calculations by different researchers have used cut off pressures from varying 200MPa to atmospheric pressure.

Cut Off Pressure

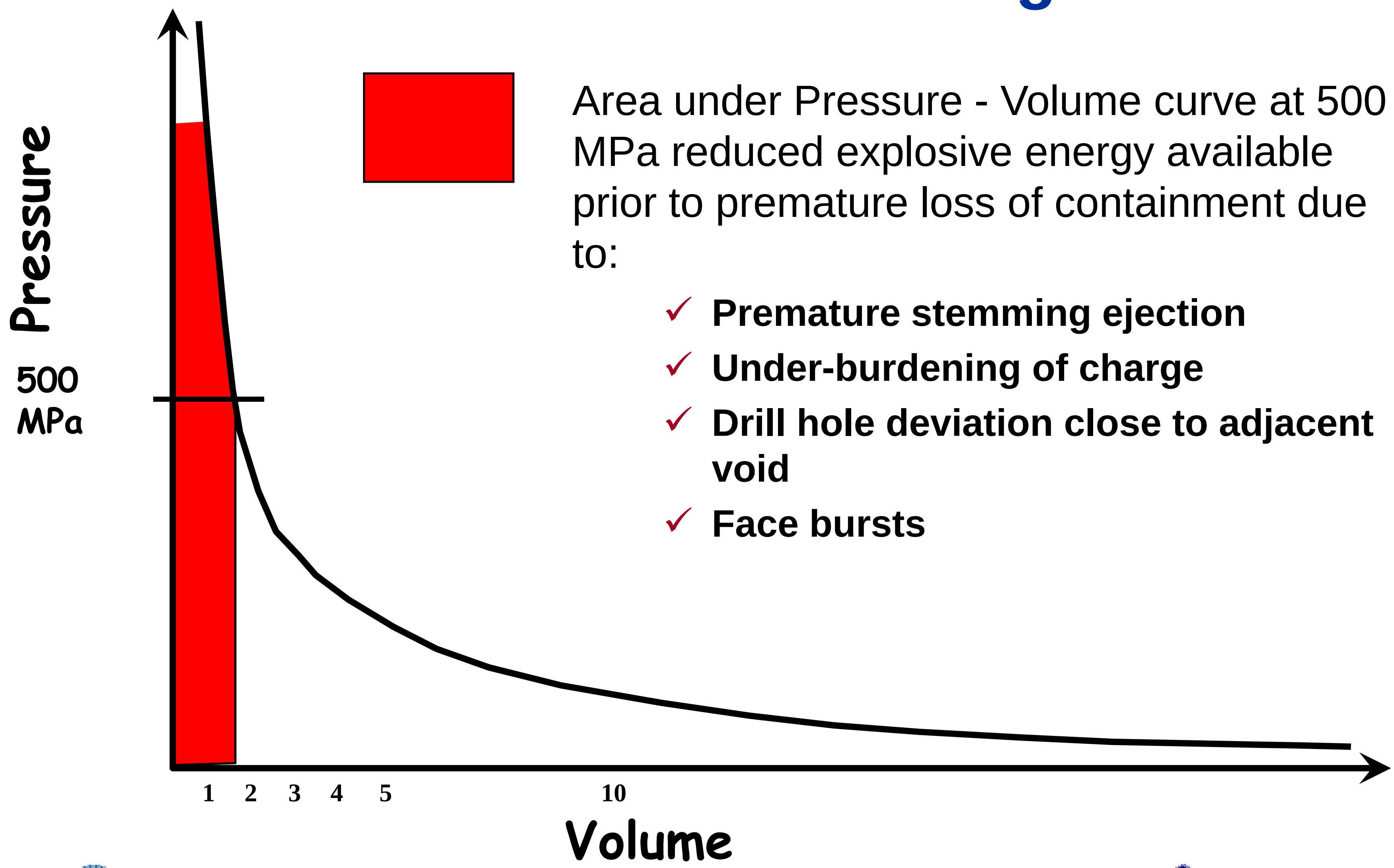


Area under P-V curve at 200 MPa is the explosive energy to that cut-off pressure

Area under P-V curve at 100 MPa is the explosive energy to that cut-off pressure

Area under P-V curve at 20 MPa is the explosive energy to that cut-off pressure

Premature Venting



Area under Pressure - Volume curve at 500 MPa reduced explosive energy available prior to premature loss of containment due to:

- ✓ **Premature stemming ejection**
- ✓ **Under-burdening of charge**
- ✓ **Drill hole deviation close to adjacent void**
- ✓ **Face bursts**

Absolute Weight Strength (AWS)

This is the theoretical absolute energy available, based on the ingredients of the explosive.

- ✓ **Energy calculated by Thermodynamic Codes (ideal) (i.e. computer models of the detonation chemistry and energy of the reactions)**
- ✓ **Usually expressed as MJ/kg, Kcal/kg or Kcal/lb of explosive**
- ✓ **AWS of ANFO is 3.73 MJ/kg (890 Kcal/kg) for 94% AN and 6% Fuel Oil.**
- ✓ **Explosive efficiency varies from 35% to 90% of maximum energy (i.e. the actual energy delivered in a blast can be 35% to 90% of theoretical maximum)**

Relative Weight Strength (RWS)

This is the ratio of energies of a unit weight of explosive compared to an equal weight of ANFO

- **RWS for an explosive is the AWS of the explosive divided by the AWS of ANFO, expressed as a percentage:**

$$RWS_{explosive} = \frac{AWS_{explosive}}{AWS_{ANFO}} \times 100$$

Absolute Bulk Strength (ABS)

The energy available in a unit volume of explosive.

- **ABS for an explosive is its AWS multiplied by its density.**

$$ABS_{explosive} = AWS_{explosive} \times \rho_{explosive}$$

Where $\rho_{explosive}$ is the density of the explosive

$$ABS_{ANFO} = 3.73 \text{ X } 0.85$$

$$= 3.17 \text{ MJ/litre (757 Kcal/cc)}$$

Relative Bulk Strength (RBS)

The ratio of the energies available in a given volume of explosive compared to an equal volume of ANFO

- ✓ **RBS for an explosive is the ABS of the explosive divided by the ABS of ANFO, expressed as a percentage:**

$$RBS_{explosive} = \frac{ABS_{explosive} \times 100}{ABS_{ANFO}}$$

Energy / Strength

- Energy can be measured or calculated
- Measurement techniques include :
  - ✓ Underwater test
  - ✓ Ballistic mortar
- Some energy losses associated with measurements, therefore they are always less than calculated
- Effective energy is the energy transformed into useful rock fragmentation and rock displacement

Critical Diameter D_{crit}

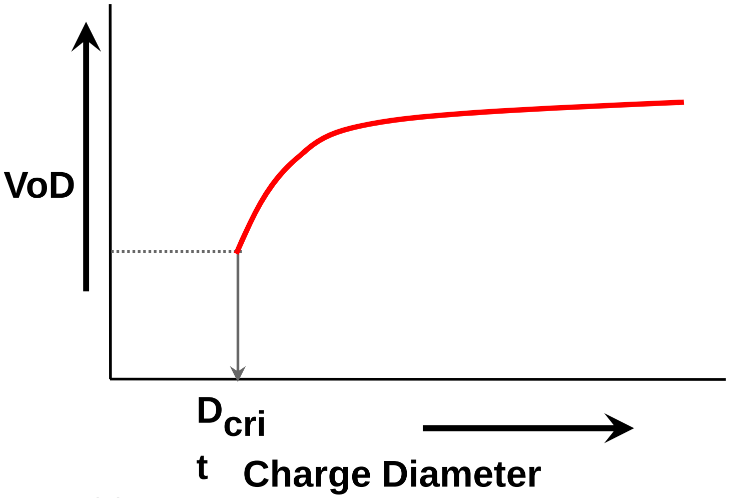
Defined as the minimum diameter at which a stable detonation can propagate.

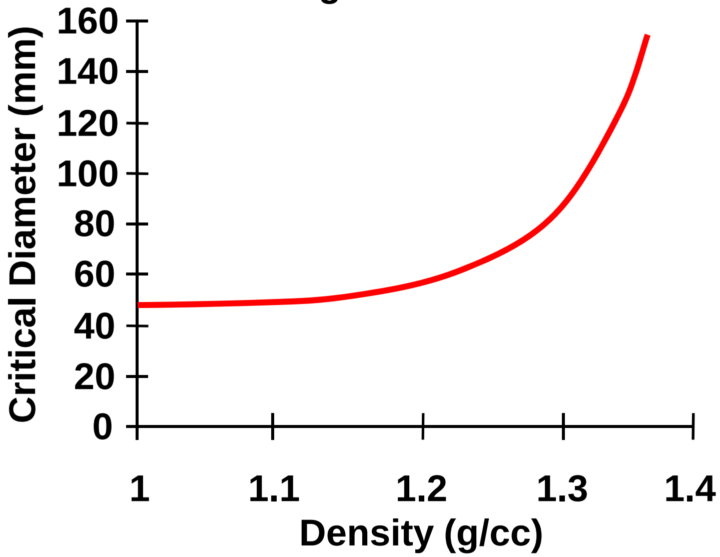
- ✓ **Ideal explosives, 1 mm (0.04 inch)**
- ✓ **Non-ideal explosives, can be up to 200 mm (8 inch)**
- ✓ **D_{crit} depends on the level of confinement**

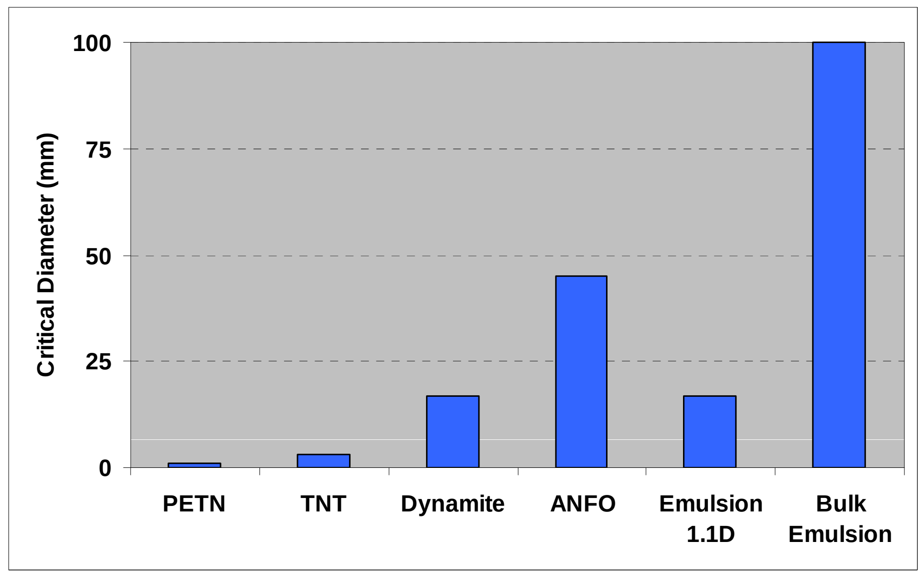
D_{crit} is important for determining hole size/explosive type compatibility

- ✓ **D_{crit} is determined predominantly by the size of the reaction zone**
- ✓ **Density also has an effect on D_{crit}**

Critical Diameter







Confinement

Confinement refers to the strength of the walls of the container in which the explosive is detonating.

- **Standards are:**
  - ✓ **Unconfined - usually taken as a cardboard tube**
  - ✓ **Confined - usually taken as a Schedule 40 Steel tube**
- **Increasing confinement:**
  - ✓ **Increases the VOD**
  - ✓ **Can determine the type of reaction**
    e.g. black powder burns unconfined but deflagrates when confined
  - ✓ **Therefore can determine efficiency of energy release and potential for NOx fumes**

Safety Properties

- **Sensitivity to:**
  - ✓ **Initiation**
  - ✓ **Impact**

Sensitivity

Defined as ease of initiation of explosive (i.e. minimum energy required to initiate detonation)

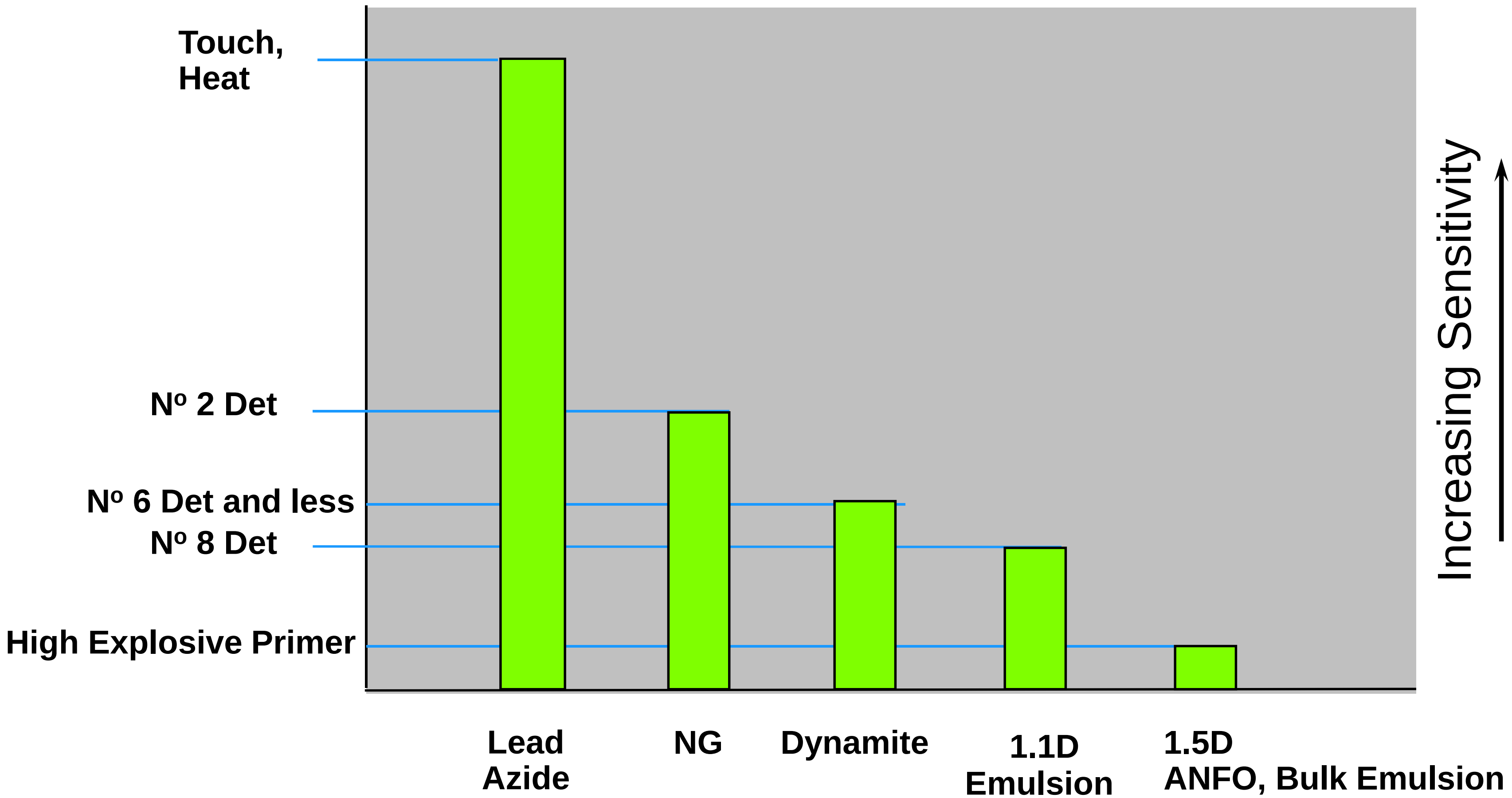
- ✓ **Varies with composition, diameter, temperature and pressure**
- ✓ **High Explosive (1.1D) defined as sensitive to No 8 strength detonator or 50gr/ft detonating cord,**
- ✓ **Blasting Agent 1.5D requires a high explosive booster for initiation**
- ✓ **Sensitivity can be altered by incorrect application**

Note: some blasting agents can become detonating cord sensitive (eg by crushing the AN prills in ANFO) and side initiate with the detonating cord downline by-passing in-hole delays in Slider Primers.

Sensitivity

- **Testing includes:**
  - ✓ **Minimum detonator / primer**
  - ✓ **Critical diameter**
  - ✓ **Impact**
  - ✓ **Critical density**
  - ✓ **Air Gap sensitivity**

Sensitivity



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