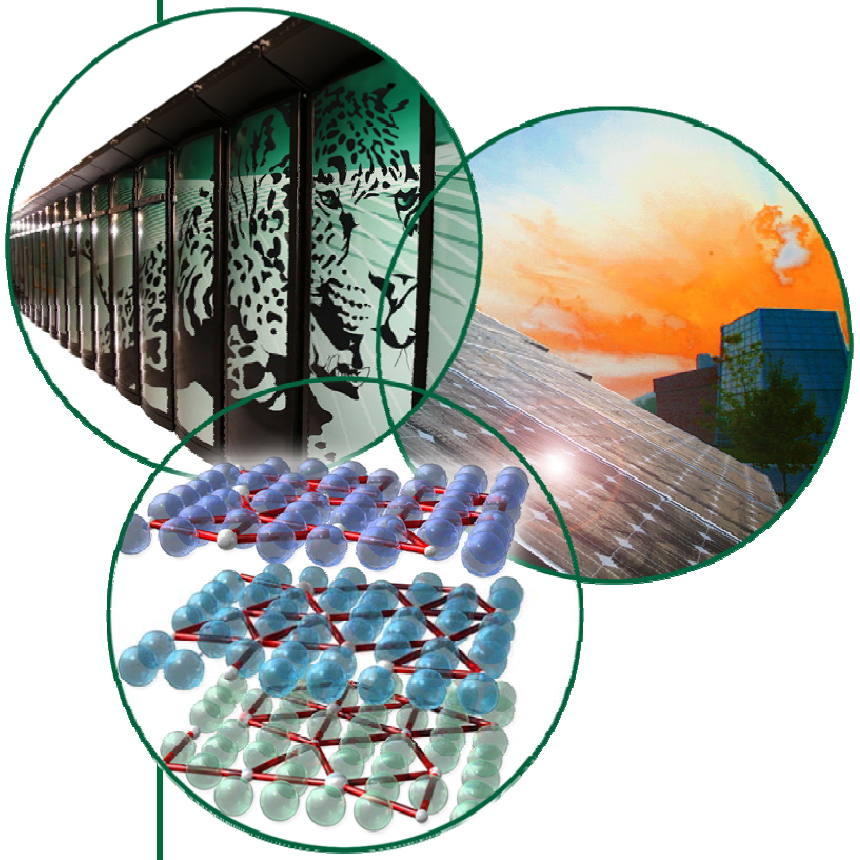
Intro to Explosives: Terminology, Technology, and Effects



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U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Overview

- Introduction
- History of explosives
- Classes and forms of explosives
- Terminology/Physics
- Effects
- Defeat

History of Explosives

- In the US and Canada alone, more than 6 billion pounds of explosives and 75 million detonators are used per year. Coal mining accounts for two-thirds of consumed explosives of which more than 80% of it is ANFO
- 668 A.D.
  "Greek-fire" used in battle
- 850 A.D.

  Chinese invent gunpowder
- 1200 A.D.
  Arabian author Abd Allah records use of saltpeter as main ingredient of black powder

Byzantine ship using Greek fire in the late 11th century

History of Explosives

- 1242
  English Friar Roger Bacon publishes gunpowder formula
- 1380
  German Franciscan Monk, Berthold Schwarts developed gunpowder and its use in guns

- 1675
  First powder mill in U.S. constructed in Milton, Mass.
- 1750
  American inventor Benjamin Franklin encases and compresses powder in cartridges

History of Explosives

- 1846
  Italian chemist Ascanio Sobrero discovers nitroglycerine
- 1863
  Wilbrand invents Trinitrotoluene (TNT)
- 1864
  Swedish inventor Alfred Nobel develops first detonating blasting cap
- 1866
  Swedish chemist Alfred Nobel invents dynamite by mixing kieselguhr with nitroglycerine

Alfred Nobel

History of Explosives

- 1875
  Nobel patents blasting gelatin
- 1888
  Nobel invents ballistite, a dense smokeless powder
- 1902
  Detonating cord introduced in Europe
- 1907
  Consumption of black powder in U.S. more than 287 million pounds

History of Explosives

- 1914
  Fifty-one mile Panama Canal opens, largest engineering project to date, using more than 67 million pounds of dynamite
- 1938
  Modern PETN-filled fabric-covered detonating cord introduced in U.S.
- 1940's
  WWII drives propellant and explosives production
- 1990's-present
  Current drive to develop "green" explosives, more stable combinations of existing explosives

Classes/Forms of Explosives

- Explosives are classified as low or high by detonating velocity and shattering effect.
- An arbitrary figure of 3300 fps is used to distinguish between burning/deflagration (low explosive) and detonation (high explosive).

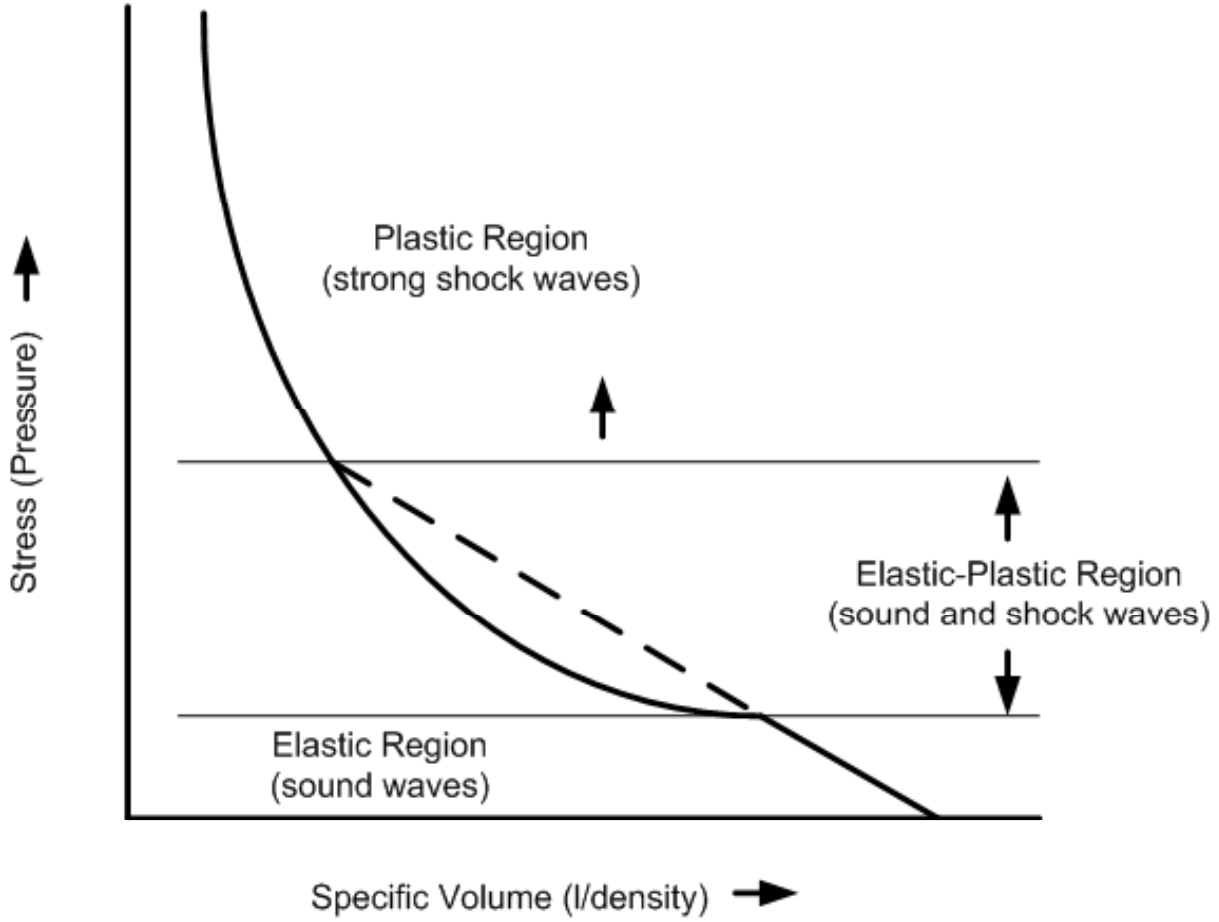
Classes/Forms of Explosives

- Low
  - Propellants, motor/rocket fuels, gun powders, pyrotechnics
- High (Primary)
  - Detonators, main charges (PETN, TNT, RDX, HMX, C-4, ANFO)

- Forms:
  - Pressings, plastic bonded (machinable), putties, extrudables, slurries and emulsions, binary or two component (liquids and solids), blasting gelatin, liquids, and gases

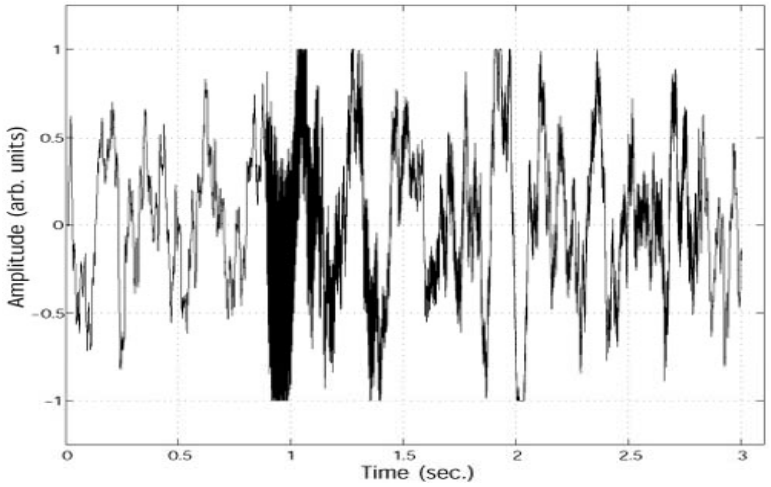
Terminology/Physics

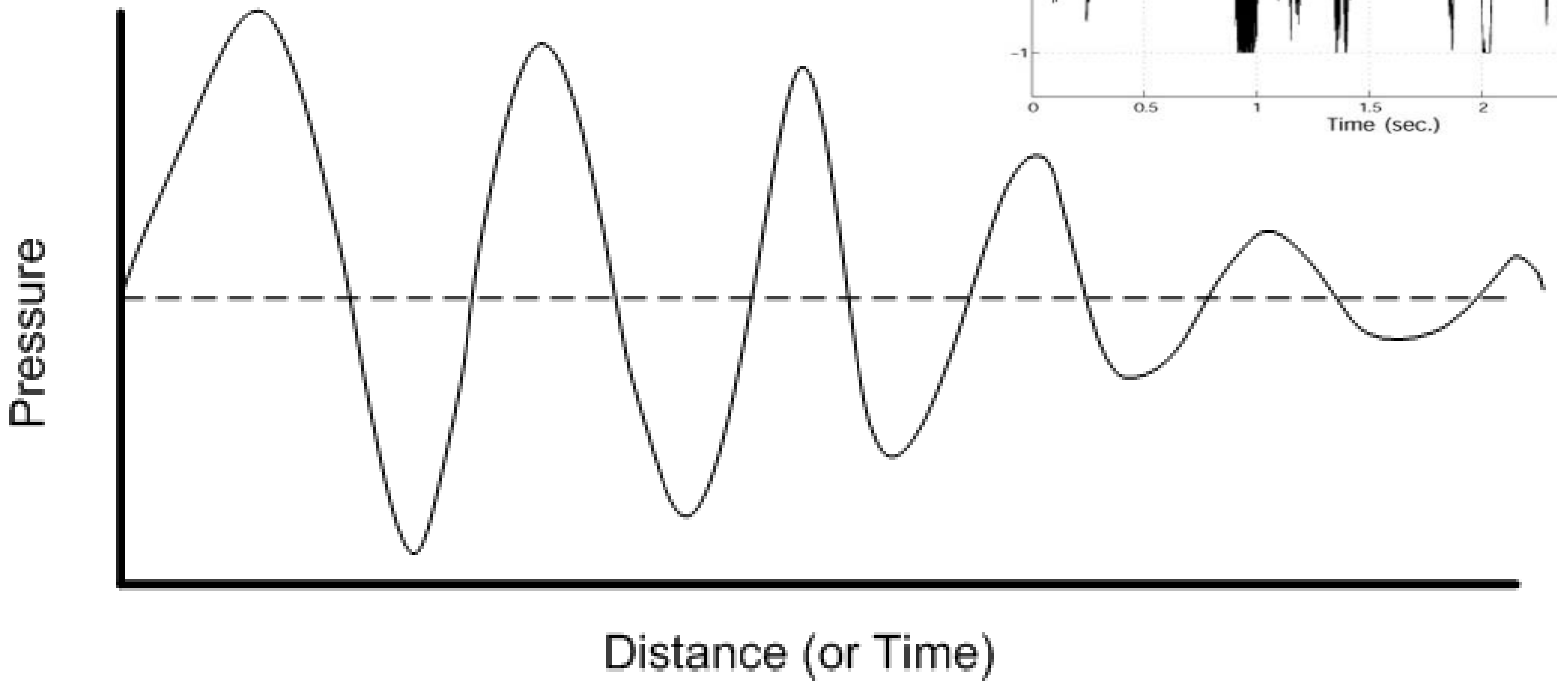
- Stress/Strain relationships



Terminology/Physics

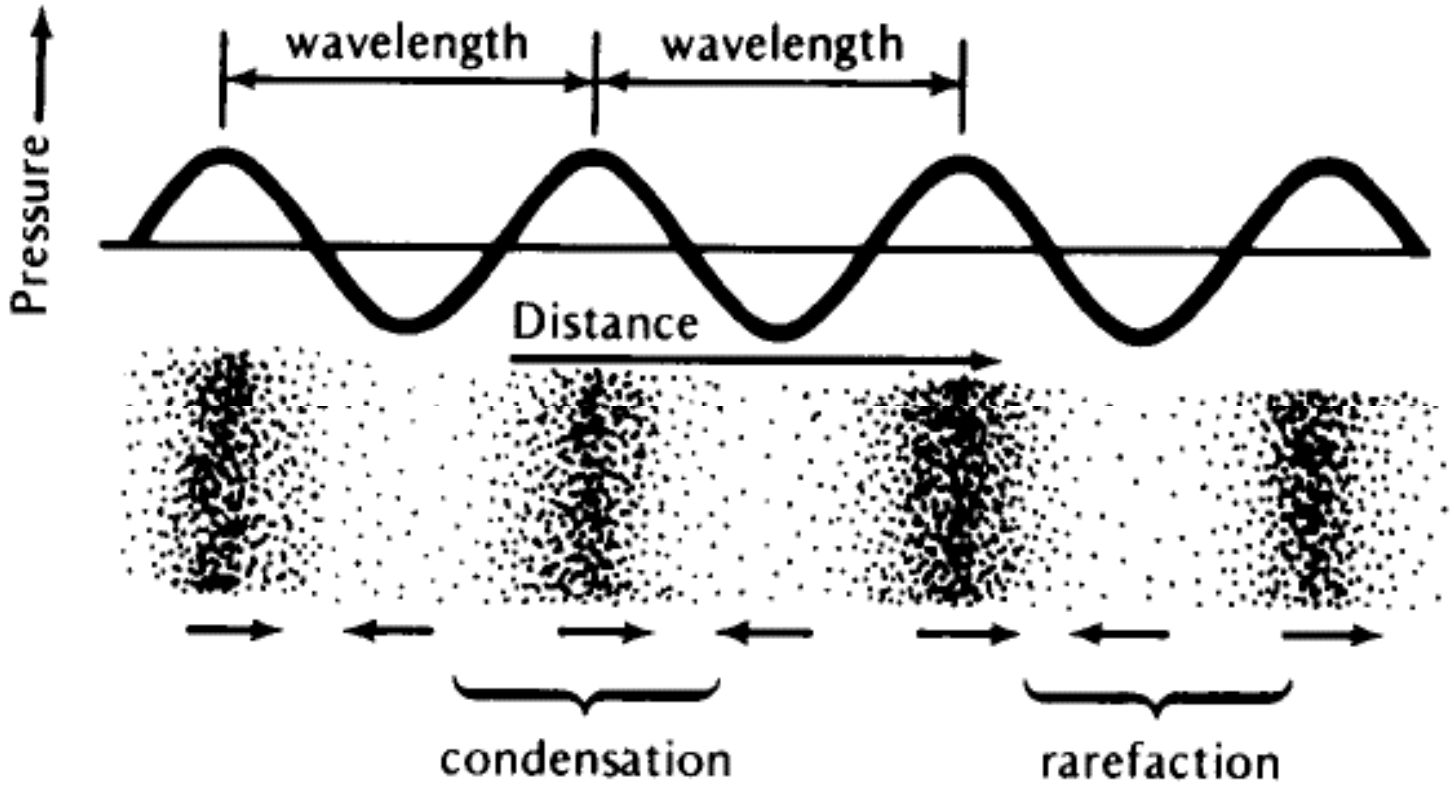
- Sound waves (attenuation)





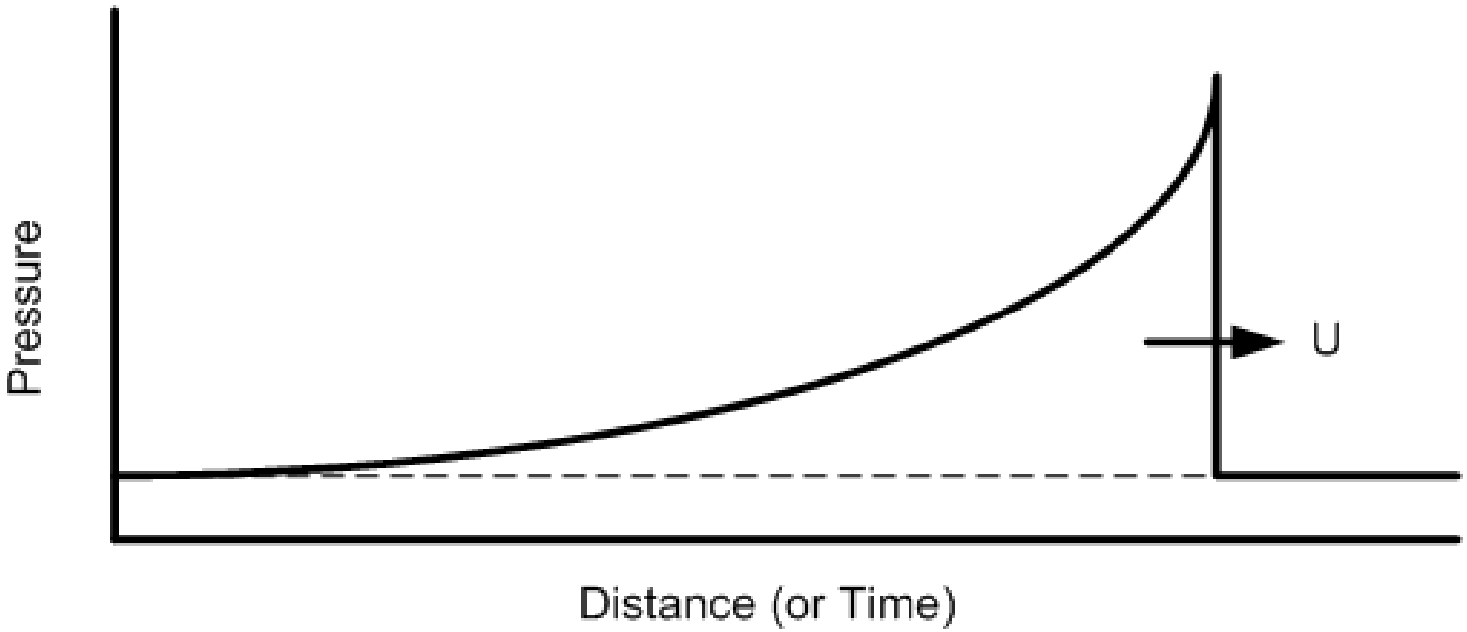
Terminology/Physics

- Sound waves (condensation and rarefaction)



Terminology/Physics

- Shock waves

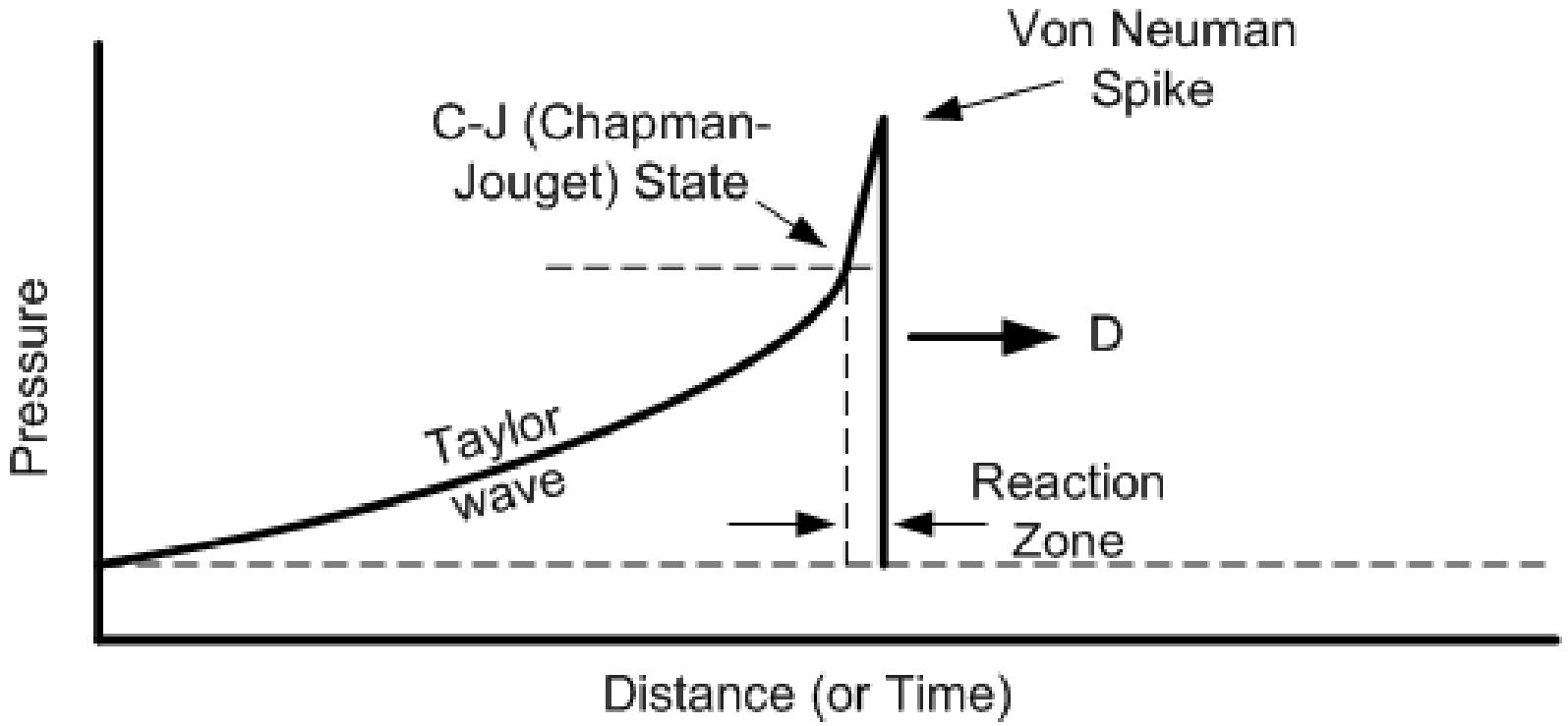


Terminology/Physics

- 100 tons detonation

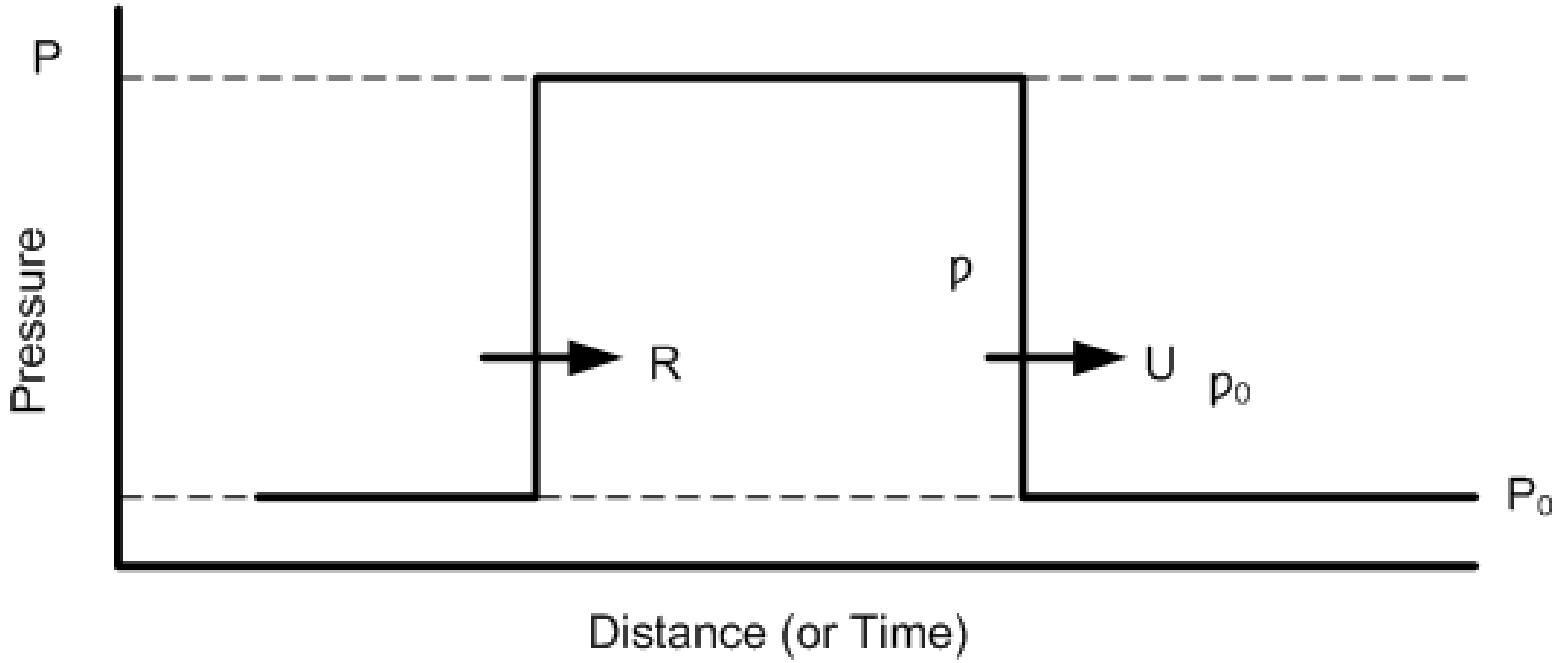
Terminology/Physics

- Detonation waves



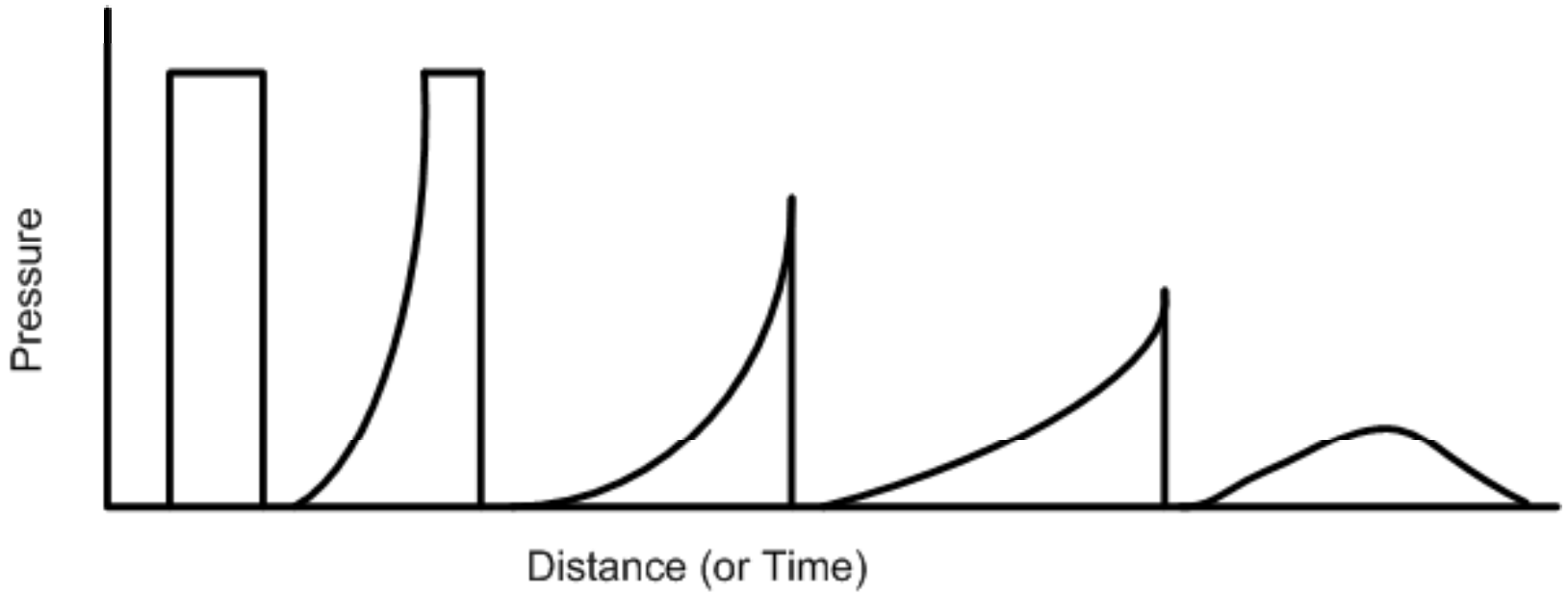
Terminology/Physics

- Square shock wave pulse



Terminology/Physics

- Attenuation of shock waves



Terminology/Physics

- Spallation (surface shattering effects in solid materials)

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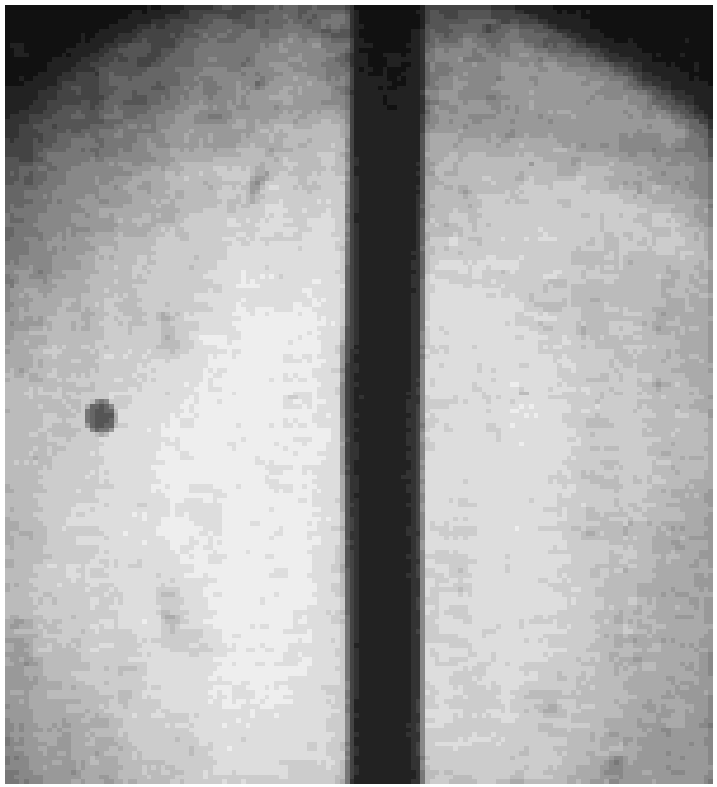
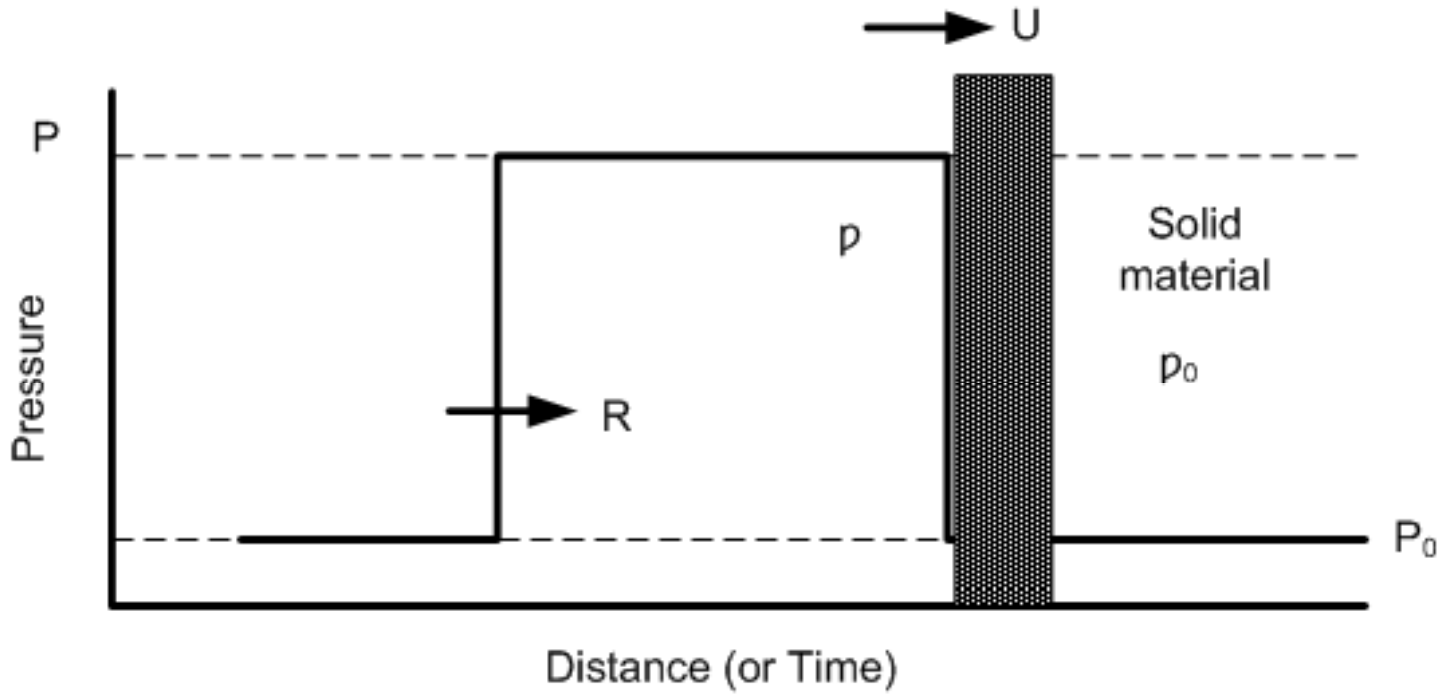


Terminology/Physics

- Spallation (the surface shattering of solid materials)



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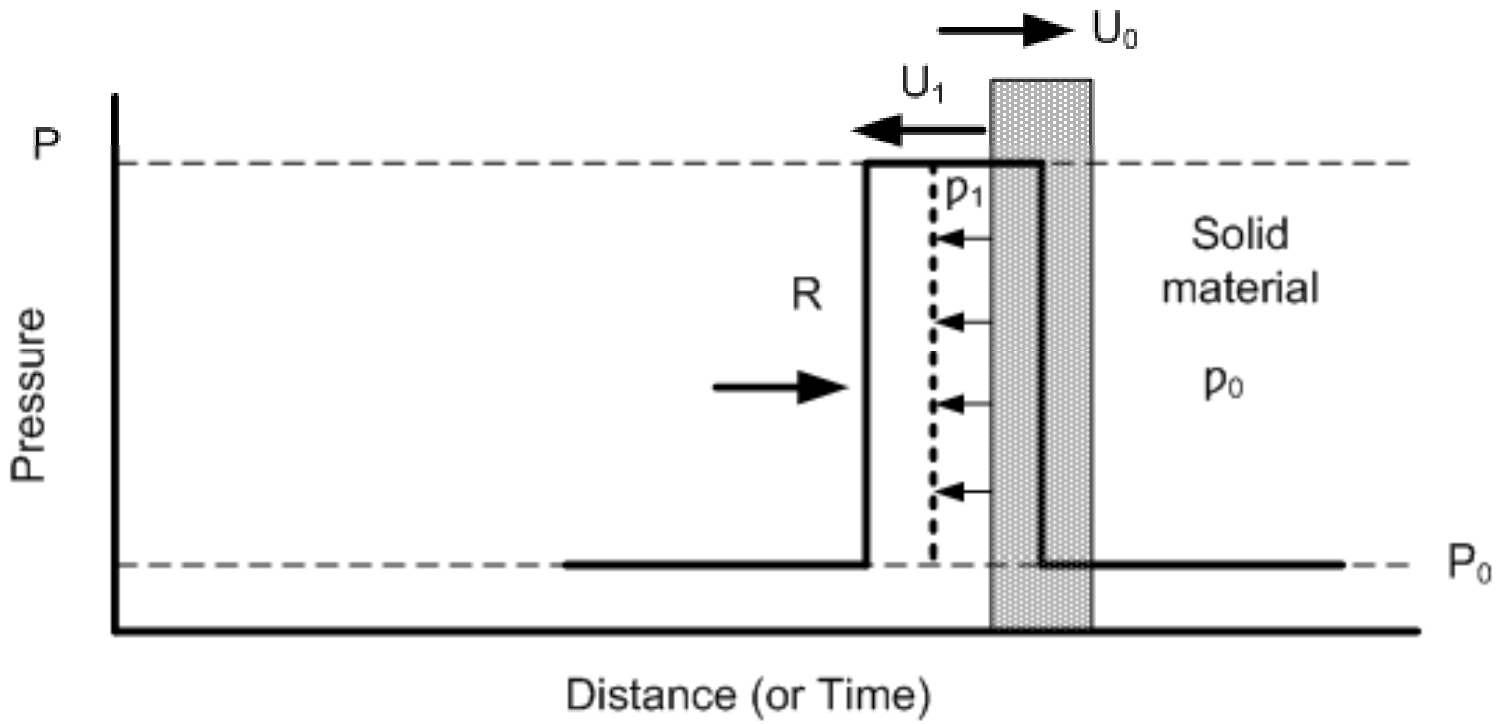
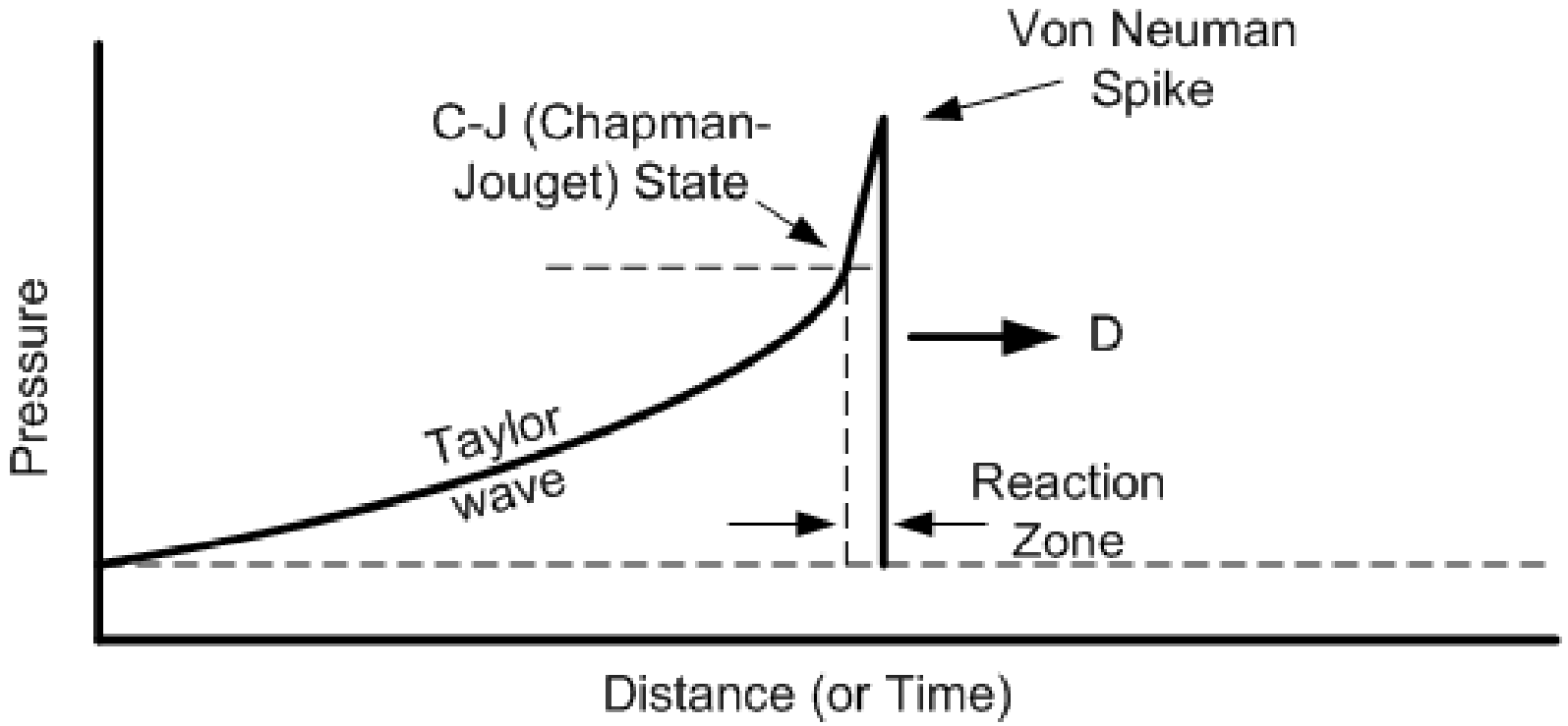


Terminology/Physics

- Brisance (shattering power)



Terminology/Physics

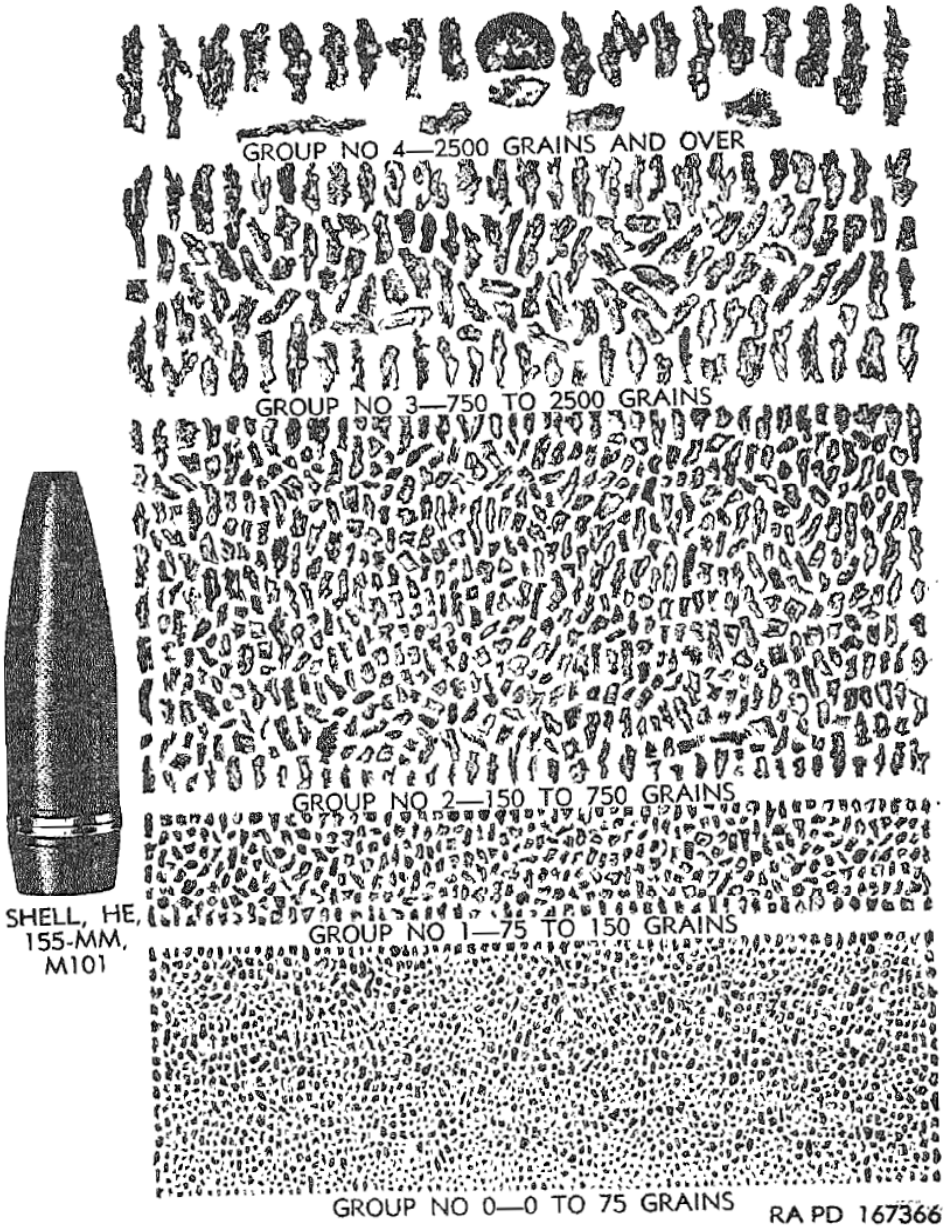
- Some common explosive numbers

Explosive	Density (g/cm^3)	Detonation Velocity (km/s)	C-J Pressure (kbar)	Heat of Detonation (kcal/g)
Baratol	2.550	4.87	140	0.72
Composition B-3	1.715	7.89	287	1.40
Composition C-4	1.590	8.04	257	1.40
HMX	1.890	9.11	390	1.48
HNAB	1.600	7.31	205	1.42
HNS	1.600	6.80	200	1.36
NG	1.590	7.65	253	1.48
PBX-9404	1.840	8.80	375	1.42
PBX-9407	1.600	7.91	287	1.46
Pentolite (50/50)	1.700	7.53	255	1.40
PETN	1.770	8.26	335	1.51
RDX	1.767	8.70	338	1.48
TACOT	1.610	6.53	181	1.35
TATB	1.880	7.76	291	1.08
TETRYL	1.710	7.85	260	1.45
TNT	1.630	6.93	210	1.29
Lead azide	3.800	5.50	299	0.37
Lead syphnate	2.900	5.20	204	0.46

Terminology/Physics

- Brisance (test chambers)

Terminology/Physics



Terminology/Physics

- Shaped charges (explosively-formed projectiles)

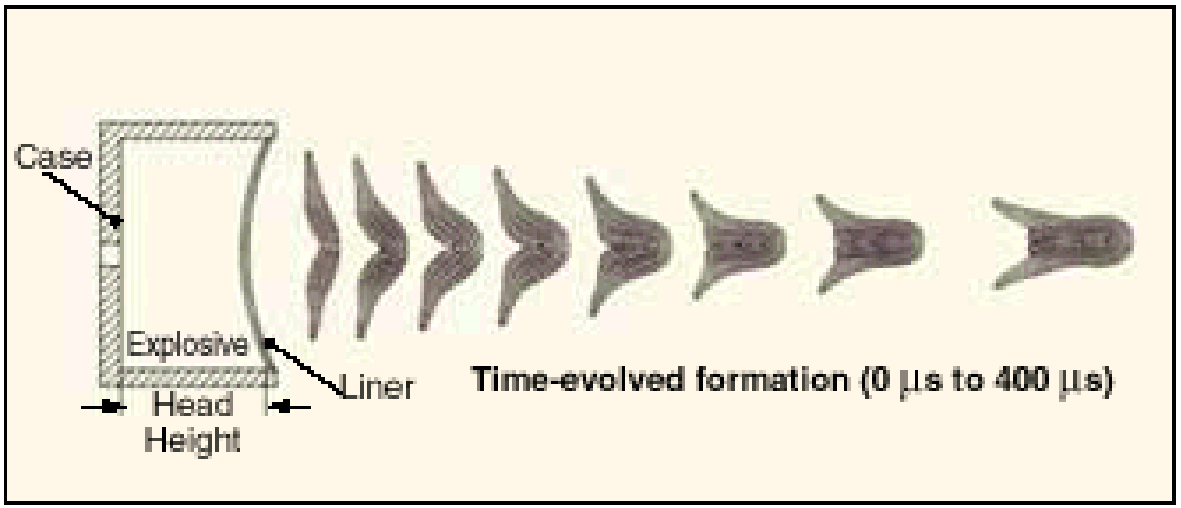
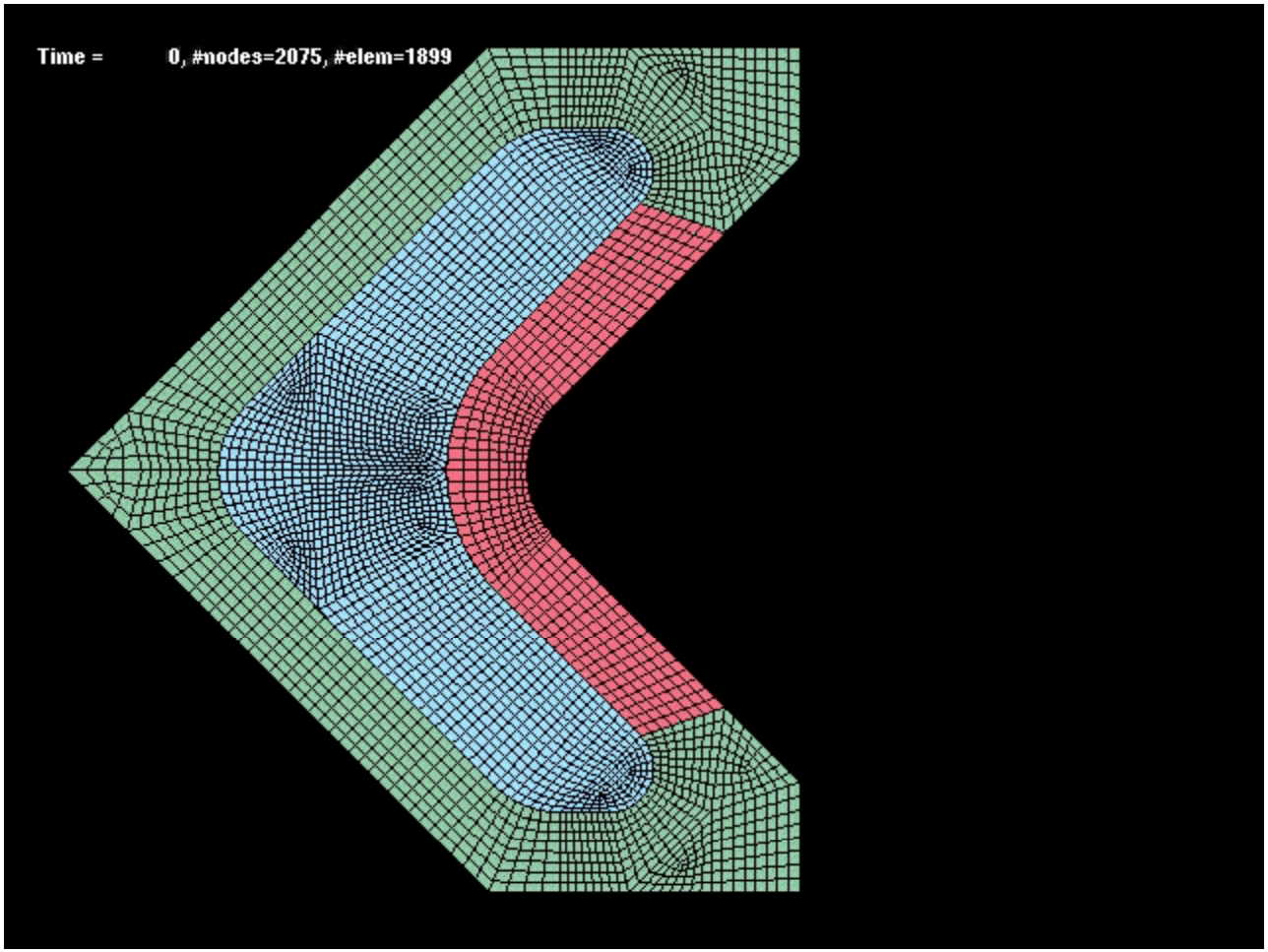


Figure 1. Formation of an EFP warhead

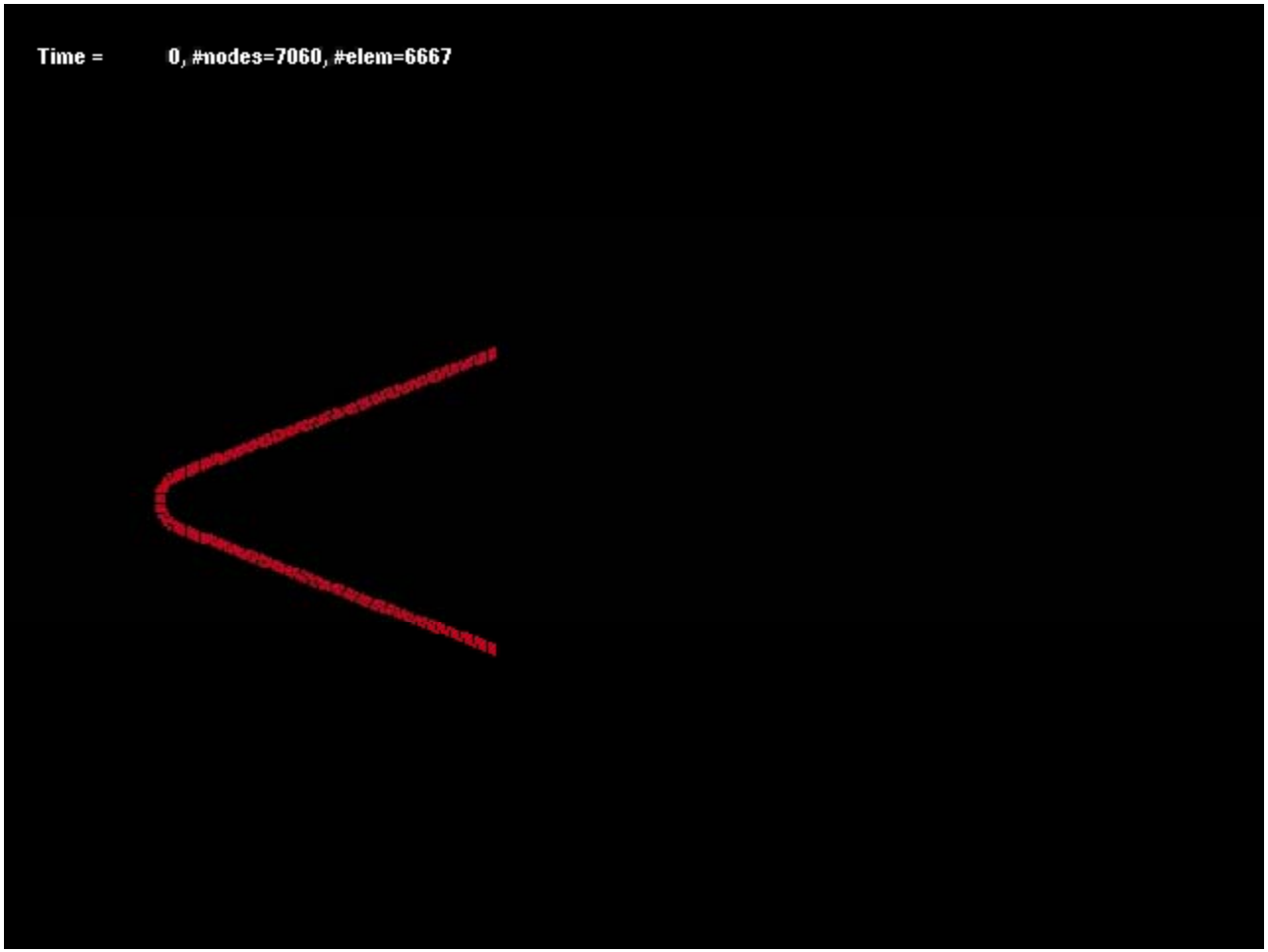
Terminology/Physics

- Shaped linear charges



Terminology/Physics

- Shaped conical charges



Terminology/Physics

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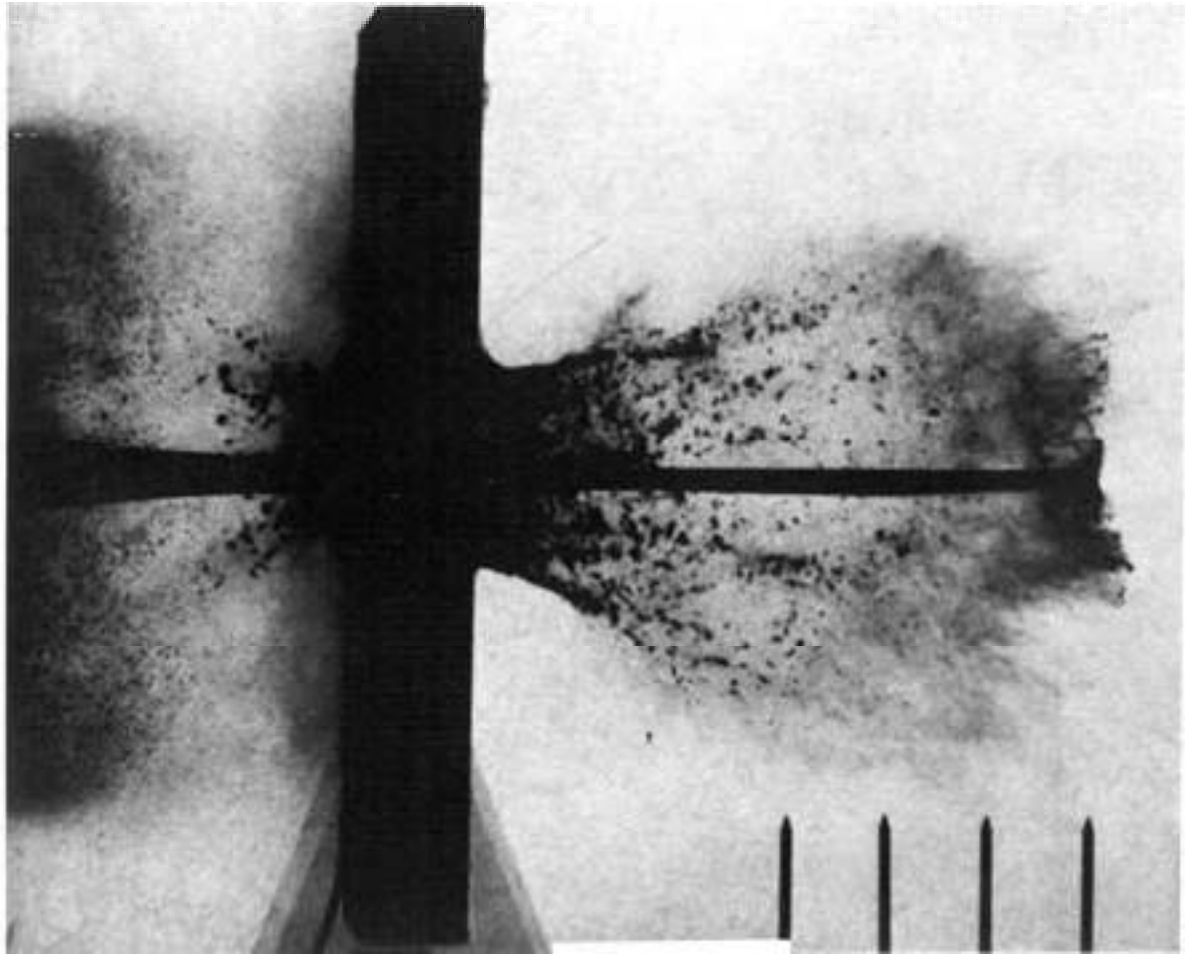
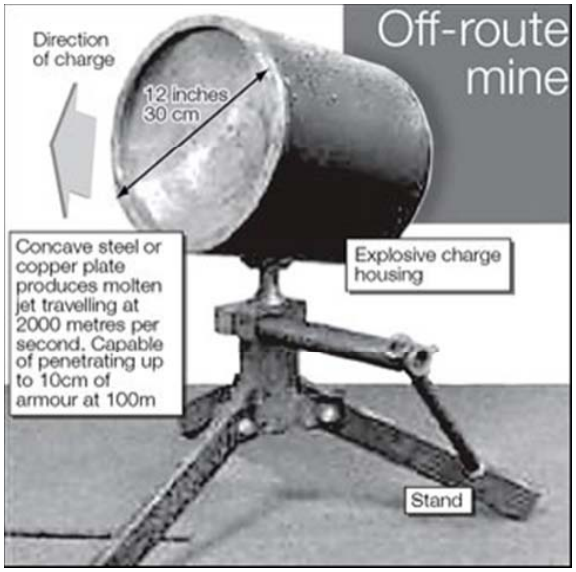
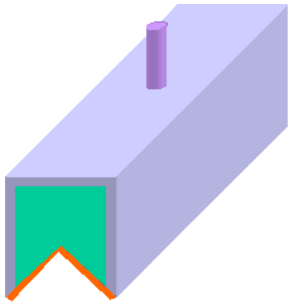


Terminology/Physics

- Shaped charges





Effects

- When detonation occurs, 3,000 - 7000 F gases are formed in 1/10,000 of a second
- Generally, 1 gram explosive = 1 liter and 1200 calories heat produced
- Gases exert ~700 tons psi on the atmosphere (at point of detonation)
- Velocities up to 13,000 mph or 29,900 fps

Effects

7000 lbs
ANFO

Effects

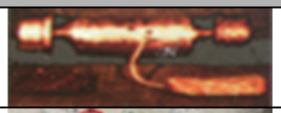
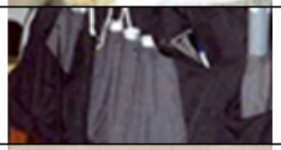
1000 lbs shaped charge

Effects

Effects

Peak overpressure	Maximum wind speed	Effect on structures	Effect on the human body
1 psi	38 mph	Window glass shatters	Light injuries from fragments occur
2 psi	70 mph	Moderate damage to houses (windows and doors blown out and severe damage to roofs)	People injured by flying glass and debris
3 psi	102 mph	Residential structures collapse	Serious injuries are common, fatalities may occur
5 psi	163 mph	Most buildings collapse	Injuries are universal, fatalities are widespread
10 psi	294 mph	Reinforced concrete buildings are severely damaged or demolished	Most people are killed
20 psi	502 mph	Heavily built concrete buildings are severely damaged or demolished	Fatalities approach 100%

Defeat

	Threat Description		Explosives Mass[1] (TNT equivalent)	Building Evacuation Distance[2]	Outdoor Evacuation Distance[3]
High Explosives (TNT Equivalent)		Pipe Bomb	5 lbs 2.3 kg	70 ft 21 m	850 ft 259 m
		Suicide Belt	10 lbs 4.5 kg	90 ft 27 m	1,080 ft 330 m
		Suicide Vest	20 lbs 9 kg	110 ft 34 m	1,360 ft 415 m
		Briefcase/Suitcase Bomb	50 lbs 23 kg	150 ft 46 m	1,850 ft 564 m
		Compact Sedan	500 lbs 227 kg	320 ft 98 m	1,500 ft 457 m
		Sedan	1,000 lbs 454 kg	400 ft 122 m	1,750 ft 534 m
		Passenger/Cargo Van	4,000 lbs 1,814 kg	640 ft 195 m	2,750 ft 838 m
		Small Moving Van/ Delivery Truck	10,000 lbs 4,536 kg	860 ft 263 m	3,750 ft 1,143 m
		Moving Van/Water Truck	30,000 lbs 13,608 kg	1,240 ft 375 m	6,500 ft 1,982 m
		Semitrailer	60,000 lbs 27,216 kg	1,570 ft 475 m	7,000 ft 2,134 m

Defeat

- Distance is the best defense in an explosion
- Detection of explosives as far away from buildings and people as possible
- Deaths/Injuries caused by fragmentation in buildings and vehicles; survival is much greater in the open
- Flat surfaces perpendicular to the blast capture more of the energy of shock waves and shaped charges
- BFRs, sandbags, avoidance, and multiple layers of armor
- Jamming, Ion disrupters
- New window films, applied materials/liners

Conclusion

- Questions?