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Explosions

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Knowledge Objectives (1 of 2)

- Describe the types of explosions.
- Discuss the characteristics of explosion damage.
- Discuss the effects of explosions and the factors that control them.

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Knowledge Objectives (2 of 2)

- Discuss the characteristics of seated, nonseated, gas and vapor, dust, backdraft or smoke, and outdoor vapor cloud explosions.
- Describe the two main types of explosives.
- Explain how to investigate an explosion scene.

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Skills Objectives

- Conduct an explosion investigation.

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Introduction (1 of 2)

- An explosion is determined by evidence.
  - Damage or change to a container caused by confinement of a *blast pressure front*
  - Impact on a person or object by an unconfined pressure front or shock wave

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Introduction (2 of 2)

- An explosion converts chemical or mechanical energy into kinetic energy.
  - Kinetic energy is energy resulting from motion.
  - The conversion produces and releases gas under pressure.
  - A loud noise may accompany an explosion.
    - Not a requirement

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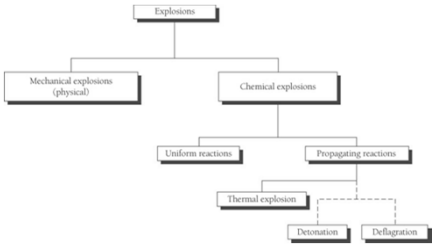
Types of Explosions



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Mechanical Explosions (1 of 2)

- No chemical change
- Purely physical reaction
- Boiling liquid expanding vapor explosion (BLEVE)
  - Most frequent type
  - Involves containers of liquid that become flammable when under pressure and at temperatures above their boiling point

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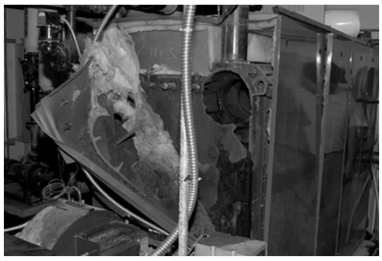
Mechanical Explosions (2 of 2)



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Chemical Explosions

- The source of the high-pressure gas is a chemical reaction.
- Fundamental chemical nature of gas changes
- Most chemical explosions involve gases, vapors, or dust mixed with air.

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Combustible Explosions (1 of 2)

- Characterized by presence of a fuel with air as an oxidizer
- The most common are caused by combustible hydrocarbon fuels
- Deflagration = slower than speed of sound
- Detonation = faster than speed of sound

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Combustible Explosions (2 of 2)

- Subtypes of combustible explosions are classified as:
  - Flammable gases
  - Vapors of ignitible liquids
  - Combustible dusts
  - Smoke and flammable products of incomplete combustion (backdraft explosion)
  - Aerosols

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Electrical Explosions

- Caused by high-energy arcing generating sufficient heat
- Example: thunder accompanied by lightning
- Not covered in NFPA 921

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Nuclear Explosions

- High pressures within primary system and secondary system are created by enormous heat produced by fission or fusion of atoms
- Not covered in NFPA 921

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Characterization of Explosion Damage

(1 of 4)

- Low-order damage: produced by pressure rising at slow rate
  - Bulged walls
  - Slightly lifted roofs
  - Windows dislodged but with glass intact
  - Large debris found nearby

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Characterization of Explosion Damage

(2 of 4)

- The windows are dislodged as a result of low-order damage to this dwelling.

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Characterization of Explosion Damage

(3 of 4)

- High-order damage: produced by rapid rate of pressure rise
  - Shattering of walls, roofs, structural members
  - Pulverized debris thrown great distances

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Characterization of Explosion Damage

(4 of 4)

- Shattered remains as a result of high-order damage are thrown a great distance.

Courtesy of Nina Scotti, NMS Investigations, Inc.

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Effects of Explosions (1 of 5)

- Blast overpressure and wave effect
  - Large quantities of gas move outward at high speed from point of origin, then return
    - Positive and negative pressure phases
  - Idealized shape is spherical, but changes due to:
    - Confinement and obstruction
    - Ignition position
    - Cloud shape
    - Concentration distribution

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Effects of Explosions (2 of 5)

- Blast overpressure and wave effect (cont'd)
  - Correlation between rate of pressure rise and damage effects

Table 19-1 Rate of Pressure Rise Versus Damage

Rate of Pressure Rise	Damage
Slow	Pushing or bulging type of damage Weaker parts of the structure will rupture first Characteristic of low-order damage
Rapid	Shattering of confining vessel or container Debris will be thrown great distances Characteristic of high-order damage

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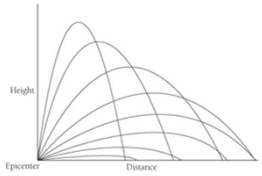
Effects of Explosions (3 of 5)

- Projected fragments effect (shrapnel)
  - May cause damage a great distance from explosion
  - Dependent on initial direction as well as weight and aerodynamics



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Effects of Explosions (4 of 5)

- Thermal effect
  - Nearby combustibles may ignite.
  - Fireballs and firebrands are possible.
  - Secondary fires may increase damage.

Table 19-2 Thermal Effects from Various Explosions

Explosion Type	Effect
Combustion	Releases heat energy Can cause secondary fires
Chemical	Releases great quantities of heat
Detonating	Produces extremely high temperatures of short duration
Deflagration	Produces lower temperatures of longer duration

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Effects of Explosions (5 of 5)

- Seismic effect (ground shock)
  - Transmission of tremors may have negligible effects
  - May cause structures to be knocked down
  - Depends on size of explosion

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Factors Controlling Explosion Effects

- Fuel type, configuration
- Containment vessel nature, size, volume
- Level of congestion and obstacles within vessel
- Ignition source location and magnitude
- Venting of containment vessel
- Relative maximum pressure
- Rate of pressure rise

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Blast Pressure Front

- Can be modified by reflection or refraction
- Reflection occurs when blast pressure front hits object, amplifying front
  - Especially severe in corners
- Refraction occurs when blast pressure front hits air of different temperature or density
  - Focuses blast

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Seated Explosions

- *Seat of explosion* = crater or area of greatest damage
- Seat may be of any size
- Generated by explosives, steam boilers, highly confined gases, BLEVEs

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Nonseated Explosions

- Occurs when fuels are dispersed or diffused
- Moderate rates of pressure rise
- Subsonic explosive velocities
- Examples:
  - Natural gas or liquefied petroleum explosions
  - Dust explosions in grain elevators and coal mines
  - Smoke explosions or backdrafts

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Gas and Vapor Explosions

- Fuel gases or the vapors of ignitable liquids are the most commonly encountered explosion.

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Interpreting Explosion Damage (1 of 5)

- Fuel–air ratio
  - Stoichiometric: the optimum ratio at which point combustion will be most efficient
  - Flame speed varies
  - Burning velocity: rate of flame propagation relative to velocity of unburned gas ahead of it
  - Transitional velocity: sum of velocity of flame front, and increase in moles and flow velocity caused by motion of gas mixture prior to ignition

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Interpreting Explosion Damage (2 of 5)

- Fuel–air ratio (cont'd)
  - Important in investigating an explosion when the following concepts are applied:
    - Adiabatic flame temperature
    - Laminar burning velocity
    - Expansion ratio
    - Laminar flame speed
    - Turbulent flame speed

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Interpreting Explosion Damage (3 of 5)

- Vapor density of the fuel
  - Ratio of average molecular weight of a given volume of gas or vapor to same of air at the same temperature and pressure
  - May affect movement of fugitive gas
  - Effects are greatest in still air

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Interpreting Explosion Damage (4 of 5)

- Turbulence effects
  - Increases flame speed and rate of combustion and pressure rise
- Nature of the confining space
  - Size and shape
  - Construction
  - Volume
  - Materials and design

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Interpreting Explosion Damage (5 of 5)

- Location and magnitude of the ignition source
  - Highest rate of pressure rise occurs if ignition source is in center of structure
- Venting
  - Can cause damage to materials in path

Courtesy of Nina Scotti, NMS Investigations, Inc.

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Strength of the Structure

- Characteristics of a structure impact its strength against an explosion
  - Glass jar vs. five-story building made of steel and gas

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Underground Migration of Fuel Gases

- Fugitive gases may enter buildings through openings into the structure.
  - Via sewer lines, utility conduits, drain tiles, and foundation walls
  - Odorant verification is necessary.
  - Gas detectors may be helpful

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Multiple Explosions

- Secondary or cascade explosions may result when gas and vapors migrate to adjacent stories or rooms.

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Dust Explosions (1 of 2)

- May occur from:
  - Agricultural products
  - Carbonaceous materials
  - Chemicals, dyes, and pigments
  - Metals, plastics, and resin

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Dust Explosions (2 of 2)

- Influencing factors
  - Particle size
  - Concentration
  - Moisture
  - Sources of ignition
  - Multiple explosions

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Backdraft or Smoke Explosions

- Fires in airtight rooms become oxygen depleted
- Generates flammable gases due to incomplete combustion
- Opening of window or door mixes air with fuels
  - Can produce low-order explosion damage

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Outdoor Vapor Cloud Explosions

- Gas, vapor, or mist release into atmosphere
- Forms cloud within fuel's flammable limits
- Often related to vessels, tankers, large amounts of fuel, low-lying areas
- Usually occur within partial restrictions of a structure

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Explosives

- NFPA recommends using specialists where explosives are concerned.
- Low explosives: characterized by deflagration
  - Smokeless gunpowder, solid rocket fuels
  - Work by pushing or heaving
- High explosives produce shattering effects.
  - Dynamite, water gel, TNT, ANFO, RDX, PETN
  - Create localized damage

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Investigating the Explosion Scene (1 of 2)

- Secure the scene.
  - From unauthorized people
  - From cross-contamination
- Establish the scene.
  - Establish the perimeter at one and one-half times the distance of the farthest piece of debris.

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Investigating the Explosion Scene (2 of 2)

- Obtain background information.
- Establish a search pattern.
  - From outer perimeter toward the area of greatest damage
  - Spiral, circular or grid-shaped
  - Overlapping edges so no evidence is missed
- Ensure safety at the scene.

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Initial Scene Assessment (1 of 3)

- If you determine that the explosion was fueled by explosives, discontinue the investigation, secure the area, and contact the appropriate entities.

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Initial Scene Assessment (2 of 3)

- Identify whether incident is explosion or fire.
- Determine high-or low-order damage.
- Identify seated or nonseated explosion.
- Identify the type of explosion.

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Initial Scene Assessment (3 of 3)

- Identify the potential general fuel type.
- Establish the origin.
- Establish the fuel source and explosion type.
- Establish the ignition source.

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Detailed Scene Assessment (1 of 5)

- Analyze effects of the explosion.
- Distinguish between preblast and postblast damage.
- Document articles of evidence.
- Determine force vectors.

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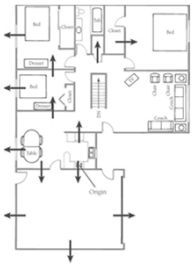
Detailed Scene Assessment (2 of 5)

- Analyze the origin (epicenter).
- Analyze the fuel source.



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Detailed Scene Assessment (3 of 5)

- Analyze the ignition source.
  - Minimum ignition energy
  - Ignition energy of the potential ignition source
  - Ignition temperature of the fuel
  - Presence of fuel and ignition source
  - Witness accounts

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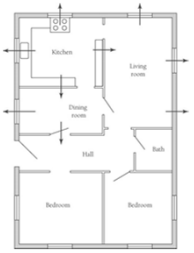
Detailed Scene Assessment (4 of 5)

- Analyze to establish cause.
  - Timeline analysis
  - Damage pattern analysis



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Detailed Scene Assessment (5 of 5)

- Analyze to establish cause (cont'd).
  - Correlation of blast yield with damage incurred
  - Analysis of damaged items and structures
  - Correlation of thermal effects

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Summary (1 of 7)

- The two major types of explosions are mechanical and chemical and are differentiated by the source and mechanism that produce them.

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Summary (2 of 7)

- The characteristics of explosion damage are low-order and high-order damage.
- The effects of an explosion include blast pressure front effect, shrapnel effect, thermal effect, and seismic effect.

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Summary (3 of 7)

- Factors controlling explosion effects are type and shape of fuel; nature, size, volume, and shape of the containment vehicle; venting of the containment vessel; relative maximum pressure achieved; and rate of pressure rise.

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Summary (4 of 7)

- Analyze the scene and evidence to establish the origin of the explosion. This is done by determining whether the explosion was seated or nonseated, the area of most damage, and the potential fuel.
- An explosion dynamics analysis is conducted to trace backward from the least to the most damaged area.

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Summary (5 of 7)

- Establishing the fuel source begins with identification of all potential fuels at the scene. These fuels are then compared with the physical damage criteria to see if one meets them all.

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Summary (6 of 7)

- To establish the ignition source, identify all potential sources, and look for remnants that may identify them. Analyze each potential source and compare with the fuel to see whether it could be the ignition source.

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Summary (7 of 7)

- Cause may be established through determination of the presence of fuel and ignition at the same time.
- Analysis can include timeline analysis, damage pattern analysis, debris analysis, relative structural damage analysis, correlation of blast yield with damage analysis of items in the structure, and correlation of thermal effects.