General Overview:

(1) Controlling Documents
(2) Program Management
(3) What is an explosive?
(4) Hazards
(5) Explosives Safety Site Plans-Protect the Public
(6) NNSA Research and Development
(7) Work Planning and Control-Protect the Workers
(8) Other Considerations
(9) Blending Industrial Hygiene and Explosives Safety
10 CFR 851, *Worker Safety and Health Program*, Appendix A, Section 3, *Explosives Safety*, states: “Contractors must comply with the policy and requirements specified in the appropriate explosives safety technical standards.”

The Department of Energy *Explosives Safety Standard (DOE-STD-1212-2019)*, is the controlling document for all explosives operations at NNSA (2019 Revision Just Released!).

Local Site Specific Requirements - Work Control/SOPs, Training Programs, Institutional ESC, Peer Reviews, Policies and Procedures (Always More Stringent).
DOE/NNSA Explosives Safety Committee promotes DOE/NNSA policy and meets twice per year. The Committee reviews, evaluates, and recommends proposed changes to the standard. Each NNSA site that works with explosives has two local Authorities Having Jurisdiction (AHJs):

1. A federal AHJ (NNSA Field Office Manager/Designee) - Site Plan Approval/Exemptions
2. A contractor AHJ is an SME who is appointed by the M&O Contractor - Waivers

Each DOE/NNSA Site has one Federal and one Partner Voting Member on the DOE/NNSA ESC. Sites are also required to have a local ESC.
Serious consequences can occur if explosives are handled improperly.

**Always Obey The:**

“The Cardinal Principle of Explosives Safety is to limit exposure to a minimum number of personnel, for a minimum amount of time, to a minimum amount of explosives, consistent with safe and efficient operations.”
What are Energetic Materials?

(1) Explosives (high explosives)
(2) Propellants (low explosives)
(3) Pyrotechnics (fireworks)

Explosives and propellants, once initiated, evolve large volumes of hot gas in a short time. The difference between high and low explosives is the rate at which the reaction occurs. With high explosives, a fast reaction produces a very high pressure shock wave capable of shattering objects.
Detonation vs. Deflagration are two ways energy may be released...if the explosion moves outward at supersonic speeds (faster than the speed of sound), it’s detonation. While the action of deflagration is to push the air in front of it, objects do not explode because the rate of combustion is relatively slow.
# Explosives Hazard Divisions

<table>
<thead>
<tr>
<th>Hazard Division</th>
<th>Hazard Description</th>
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<tbody>
<tr>
<td>1.1</td>
<td>Mass Explosion</td>
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<td>1.2</td>
<td>Non-mass explosion, fragment-producing</td>
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<tr>
<td>1.3</td>
<td>Mass fire, minor blast or fragment</td>
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<tr>
<td>1.4</td>
<td>Moderate fire, no significant blast or fragment</td>
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<tr>
<td>1.5</td>
<td>Explosive substance, very insensitive (with a mass explosion hazard)</td>
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<tr>
<td>1.6</td>
<td>Explosive article, extremely insensitive (no mass explosion hazard)</td>
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</tbody>
</table>
The hazards from an explosive detonation are classified as follows:

1. Shock Wave
2. Blast Overpressure
3. Fragmentation
   1. Primary fragments
   2. Secondary fragments
4. Fire
5. Heat
6. Noise
7. Fumes
8. Propagation
9. Chemical Toxicity/Asbestos
10. Deflagration to Detonation
Blast and Fragments
Explosives Safety Site Plans - Approved by Field Office Managers as Risk Acceptor

(1) Physical limits that can’t be breached without incurring risks: Blast, Fragments, Thermal Hazards
(2) Personnel Limits
(3) Net Explosives Weight (Amount and Type/1.1)
(4) Required Distance to Inhabited Buildings, Public Transportation Routes, Operating Facilities, Storage Magazines
(5) Map with Clear Zones

Keep the public out of the Hazard Zones!
Explosive Safety Quantity Distance (ESQD)
Work Planning and Control - LLNL Team Effort

Always Includes:
Researchers, Industrial Hygiene, Safety, Explosives Safety Engineers, Environmental Specialists, Radiation Health, AND Work Planners
Work Planning and Control - Team Effort

1. Know Health Hazards
2. Sensitivity, Physical Hazards
3. Ventilation - LEV
4. Safety Data Sheets - Exposure Limits
5. Equipment, Facility Construction
6. PPE - Gloves/Resp. Protection/Hearing Protection
7. Training and Qualification
8. Medical Surveillance
9. Inventory, Signage, NEW
10. Access Control, Personnel Limits
11. Good Housekeeping
12. Storage and Compatibility Groups
13. Transport - DOT-approved Containers, Critical Lift Plan
Explosives materials, components (additives or adhesives), and materials such as organic solvents used in explosives processing can be toxic when inhaled, ingested, or absorbed through the skin.

(1) Most frequently reported health effects: skin rash
(2) Systemic poisoning (affects bone marrow and liver)
(3) Some explosives are vasodilators (headache, low BP, chest pains and possibly heart attacks)
(4) Legacy detonators contain asbestos
(5) Soot, Carbon Monoxide, Hydrogen Gas
(6) Hearing loss after unintentional detonation

Medical Surveillance is provided to HE Handlers at LLNL
Since explosives can react violently, energetic materials need to be protected from abnormal stimuli or environments. Including:

1. Friction
2. Excessive pressures and temperatures
3. Impact
4. Shock
5. Pinching
6. Open flames and sparks
7. Contamination
8. Contact with incompatible materials
9. Static Electricity
Engineering and Administrative Controls

Performed remotely with Interlocks, Warning Devices, Barriers, Shields

Eliminate Static Electricity - Use Conductive Flooring, Shoes, Mats, Wristbands

Bonding and Grounding of Equipment

Humidification of Room

Lightning Protection Systems/Warning

Firing Tanks, Chambers

Building Materials/Construction
Personnel shall be properly trained before they are assigned to explosives operations or operate explosives transport vehicles.

LLNL has Implemented a Comprehensive TQP for Explosives Handlers: Training (Classroom and 40+hr. On-line), Two-week Texas A&M Hands-on Training, 12 Seminars, OJT Mentoring, Written Exam, Oral Board and Final Management Approval.

Lessons Learned Incorporated Into Training
LANL has developed a course on HME for DoD personnel. Homemade Explosives - Not Rocket Science- Internet Recipes

Where Can You Find Materials/Equipment?
Many Recipes Can Be Performed With Commonly Available Ingredients. HMEs Are Unpredictable Materials In An Unpredictable Environment.

Fuel-oxidizer: Two or More Components Required.
Fuels- Petroleum, Vaseline, Sawdust, Antifreeze, Sugar, Bat Guano, Sulfur, Carbon, Urea, Powered Metals
Oxidizers - Ammonium Nitrate, Potassium Chlorate, Hydrogen Peroxide, Nitric Acid
Explosives Detection Devices

Solids and liquids
- Colorimetry - Identifies Class
- Raman, Infrared - Bulk

Vapors (Dogs, Fido, IMS)

Field Tests (Hammer and Flame Tests)

Air Sampling - Asbestos, Solvents, Organics

Noise

Sensory Clues (Odor, Appearance, Precursors?)

Routine IH Monitoring in Labs?
Many of the NNSA Sites Perform R&D to Develop Insensitive High Explosives (IHE) which is less susceptible to accidental detonation and is safer to handle, but effective.

Analytical, mechanical, safety and performance testing occur at each step.
(1) Before initiation of work analyze all explosives hazards, controls, equipment and experimental steps.
(2) Conduct Process Hazard Analysis, Peer Review and Obtain Local ESC Approval
(3) Complete Work Control Document

Start Small and Scale Up - Phase-by-Phase Approvals
End with Intentional Detonation (Blow it Up!)

Laboratory Testing Protocols (Five Tests to Ensure the Safety and Stability of the Energetic Materials)
Synthesis of explosive molecules  
Mixing of explosive formulations  
Pressing into solid form  
Machining into desired shape  
Subassembly of components

Analytical, mechanical, safety, and performance testing are to occur after each of these steps to help ensure quality control.

Source: GAO analysis of National Nuclear Security Administration documents. | GAO-19-449
## Raw Explosives

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>HMX</td>
<td>Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine</td>
</tr>
<tr>
<td>HNS</td>
<td>2,2',4,4',6,6'-hexanitrostilbene</td>
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<tr>
<td>PETN</td>
<td>Pentaerythritol tetranitrate</td>
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<tr>
<td>Picramide</td>
<td>2,4,6-trinitroaniline</td>
</tr>
<tr>
<td>RDX</td>
<td>Hexahydro-1,3,5-trinitro-s-triazine</td>
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<tr>
<td>TATB</td>
<td>1,3,5-triamino-2,4,6-trinitrobenzene</td>
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<tr>
<td>TNT</td>
<td>2,4,6-trinitrotoluene</td>
</tr>
</tbody>
</table>

## Plastic Bonded Explosives

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
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<tbody>
<tr>
<td>LX-04</td>
<td>(85% HMX/ 15% Viton A)</td>
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<tr>
<td>LX-07</td>
<td>(90% HMX/10% Viton A/ Orange Dye)</td>
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<tr>
<td>LX-10</td>
<td>(98% HMX/ 5% Viton A)</td>
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<tr>
<td>LX-14</td>
<td>(95.5% HMX/4.5% Estane)</td>
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<tr>
<td>LX-16</td>
<td>(96.5% PETN/3.5% OXY-461*) *OXY-461, EXON-461 and PFC-461 are equivalent.</td>
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<tr>
<td>LX-17</td>
<td>(92.5% TATB/7.5% Kel-F 800/ Red Dye)</td>
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<tr>
<td>PBX-9404</td>
<td>(94% HMX/ 3% Nitrocellulose/ 3% CEF/ 0.1% DPA)</td>
</tr>
<tr>
<td>PBX-9501</td>
<td>(95% HMX/ 2.5% Estane/ 2.5% (BDNPA/BDNPP)/ 0.04% Erganox 1010)</td>
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<tr>
<td>PBX-9502</td>
<td>(95% TATB/ 5% Kel-F 800)</td>
</tr>
<tr>
<td>XTX-8003/LX-13</td>
<td>(80% PETN/ 20% Sylgard 182)</td>
</tr>
</tbody>
</table>

## Notes
1. Colors vary and are not positive identification; natural colors age and change.
2. “PBX” and “X” prefixes denote Los Alamos (LANL) developed explosives.
Five Required Laboratory Tests to Determine Sensitivity and Stability of New Energetic Materials:

1. Drop-weight impact
2. Friction Sensitivity
3. Spark Sensitivity
4. Thermal Stability
5. Compatibility/Reactivity

Compare Results to Known Materials
Primary vs. Secondary Explosives
Earth Covered Magazines (ECM)

(1) Vegetation/Fire Protection, Climate Control, Load Limits, Signage Labeling, Wildlife, Annual Inventory

(2) Storage Review Program (HE can degrade and become unstable).

(3) A minimum of two feet of earth must be maintained over the top of each magazine, otherwise the magazine will be considered an aboveground magazine.

(4) Materials are to be free from deleterious organic matter, trash, debris, and stones heavier than 10 pounds or larger than 6 inches in diameter.
## 13 Storage Compatibility Groups (SCGs)

<table>
<thead>
<tr>
<th>Group A</th>
<th>Initiating explosives (Lead-azide, PETN, TATNB)</th>
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<tbody>
<tr>
<td>Group B</td>
<td>Detonators and similar initiating devices (Blasting caps, Low-energy initiators, Small-arm primers)</td>
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<tr>
<td>Group C</td>
<td>Bulk propellant, devices containing propellants (TATB, Smokeless powder)</td>
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<tr>
<td>Group D</td>
<td>High Explosives-DATB, LLM-105, Comp B, HMX</td>
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<tr>
<td>Group E</td>
<td>Explosive Devices that lack their own means of initiation but contain a propelling charge—Rockets</td>
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<tr>
<td>Group F</td>
<td>Explosive devices that have their own means of initiation—Grenades</td>
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<tr>
<td>Group G</td>
<td>Pyrotechnic materials and devices containing pyrotechnic substances—Flares</td>
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<tr>
<td>Group H</td>
<td>Ammunition containing both HE and white phosphorus</td>
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<tr>
<td>Group J</td>
<td>Ammunition containing both HE and flammable liquids</td>
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<tr>
<td>Group K</td>
<td>Ammunition containing both explosives and toxic chemical agents</td>
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<tr>
<td>Group L</td>
<td>Explosives or ammunition not included in other compatibility groups—Damaged or suspect HE, Experimental HE</td>
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<tr>
<td>Group N</td>
<td>Hazard Class 1.6 articles containing IHE</td>
</tr>
<tr>
<td>Group S</td>
<td>Explosives, explosives devices or ammunition presenting no significant risk—Safety fuse, thermal batteries, propellant cartridge</td>
</tr>
</tbody>
</table>
Initially, newly synthesized compounds, mixtures and explosive material and devices are automatically assigned to:

**Hazard Division 1.1 and SCG L**

Before classification can be changed, testing to determine sensitivity, stability, and handling history is required.
## Compatibility Tables

<table>
<thead>
<tr>
<th>CGs</th>
<th>A</th>
<th>B</th>
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</table>
Transportation - Qualified Drivers, DOT-Approved Shipping Containers, Inspections, Secure Vehicle/Wheels Chocked, Routes, Placards, Receiving Facilities and Facility Hallway Routes

Emergency Control Plans - Reporting, Procedures, Roles of Operating Personnel, Evacuation, Signage, Criteria for Activating Plan, etc.

Disposal - Must Consider Cradle to Grave (Decontamination, Burial, Open burning)

Intentional Detonation - EPA Permits, Access Control, Safe Distances, Diagnostic Equipment (High Speed Cameras)
NNSA places a premium on safety throughout all phases of explosives activities including research and development, testing, production, and storage. High explosives, propellants, and pyrotechnics serve essential functions in nuclear weapons.
QUESTIONS?
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